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AN EXPERIMENTAL STUDY IN THE PSYCHOLOGY OF READING

By

WILLIAM ANTON SCHMIDT

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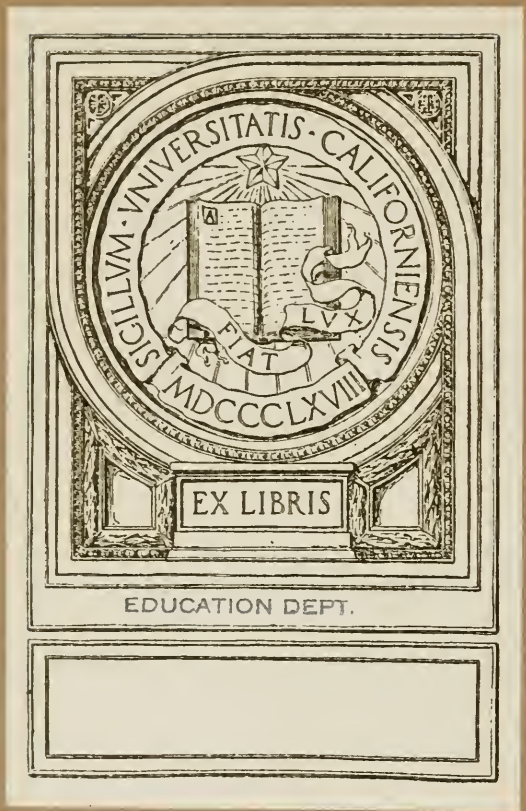
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TABLE OF CONTENTS

CHAPTER I

INTRODUCTION[1]

A recent investigation has shown that more than one-fourth of the time in the elementary schools of our cities is devoted to the teaching of reading (1)[2]. This proportion acquires material significance when viewed in the light of the fact that the teaching of reading has until recently been proverbially inefficient, especially in the case of the intermediate and grammar grades. The technique of teaching the mechanics of reading has of course undergone an almost complete revolution since 1870. The alphabet method in use for ages has been gradually discarded, while the phonic, phonetic, word, and sentence methods were being perfected and blended into a variety of superior combination methods (2). But even here there is still entirely too much clash of opinion and far too little scientific certainty. And to say the least, the most efficient method of teaching the mechanics of reading remains yet to be determined through scientific experimentation.

If we turn to the later stages in the process of teaching reading —the stages following upon the period when the mechanics of reading has been mastered—we find that improvement in practice

[1] Most of the data bearing upon this investigation were secured in the laboratory of the School of Education of the University of Chicago during the school year 1913–14. The writer gratefully acknowledges his indebtedness to Dr. F. N. Freeman for his introduction to the technique and methods of experimentation, for improvements in connection with the apparatus—particularly in so far as these bear upon the modifications which made possible measurement of eye-movement in the vertical plane—for much time in serving as a subject in connection with most preliminary and supplementary experimentation, and for much valuable advice and indispensable criticism in connection with the investigation and the manuscript. The writer is further greatly indebted to Dr. Charles H. Judd for suggesting the problem and for most valuable council and criticism. Grateful acknowledgments are also due to Principal F. W. Johnson, of the University High School, and to Principal H. O. Gillet, of the University Elementary School, for kindly co-operation in securing children, as well as to the many individuals who served as subjects in the course of the investigation.

[2] Figures in parentheses refer to corresponding numbers in the bibliography given at the end of each chapter.

has been much slower. In fact, training in this most important form of human behavior has until recently been guided almost exclusively by traditional and empirical principles. In consequence the results have been very unsatisfactory. Emphases have not infrequently been entirely misplaced, as in the case of silent and oral reading, for instance. In spite of the fact that silent reading is of far greater importance for adult life than oral reading, our schools have stressed the latter to the almost complete exclusion of the former. Similarly, adaptation to individual differences has been rather persistently ignored.

More recently, however, a marked change has been taking place. As a result, the reading process is rapidly being analyzed, and careful studies are being made of its several components, such as rate and comprehension. Individual differences are being determined, reading materials standardized, norms and standards of accomplishment established, the differences between silent and oral reading more definitely set forth, and new practices developed. This new and promising movement is due in part to the influence of the rapidly growing technical psychology of reading, the inception and development of which are traced in the next chapter, and in part it is part and parcel of the present scientific movement in education—the movement which is ruthlessly challenging all of our practices, in so far as these rest upon traditional and empirical rather than scientific principles.

Before the most advantageous and economical reconstruction of practice can be effected additional information is needed. To this end the reading process must be further analyzed and the boundaries of the psychology of reading must be materially extended. It is not sufficient, for instance, to know that reading rate is a variable. We must determine the factors which condition such variation; we must find out to what extent speed efficiency is dependent upon the number and to what extent upon the duration of fixation pauses; how it is related to age and accomplishment, and how to efficiency in comprehension; to what extent it is subject to improvement under judicious practice, and within what limits it may be developed in connection with continuous reading rather than scanning. It is essential, further, that the differences between

silent and oral reading be carefully pointed out, and that the possibilities and limitations of each be more completely set forth.

Accordingly, this investigation was undertaken for the purpose of securing such information. An effort has been made to discover the dominant reading characteristics of a large number of individuals varying widely in age and accomplishment. Similarly, the differences between silent and oral reading—especially as these are revealed by variations in the number, duration, and location of fixation pauses and by differences in reading rate—have been singled out and described. Finally, a critical analysis of binocular behavior and adjustment affords information which is of particular interest to the technical psychology of reading.

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CHAPTER II

HISTORICAL SKETCH

The scientific study of the reading process is of comparatively recent origin. The long neglect of this important field is, as Huey remarks, "a curious instance of the failure of scientists to make first-hand observation except along certain lines that have become habitual." Once initiated, however, the movement has made considerable progress—so much so, in fact, that we have today an elaborate experimental technique and a wealth of scientific data at our command. The problem has been approached from many different angles, and has as a result given rise to a variety of experimental activities, each making its specific contribution toward the building up of a comprehensive psychology of reading. We are here most immediately concerned with three types of experimental investigation, namely: (A) those approaching the problem primarily through a study of eye-movements; (B) those dealing chiefly with the perceptual process; (C) those attacking the problem from the standpoint of individual differences in speed, comprehension, and reproduction.

A. EXPERIMENTAL INVESTIGATIONS OF EYE-MOVEMENTS

1. EVOLUTION OF EXPERIMENTAL TECHNIQUE FOR THE STUDY OF EYE-MOVEMENTS

The present complicated technique for the study of eye-movements has a rather interesting history. Although earlier attempts to attack the problem by means of mechanical devices are not wanting, yet up to 1898, when Huey succeeded in utilizing mechanical registration, the after-image method and the mirror method of direct observation gave the most satisfactory results. Volkmann (1) and Lamansky (2) used the after-image method during the third quarter of the last century. The speed of the eye's movement "was measured by counting the number of after-images produced during a given movement of a pencil of light

flashed into the eye at regular intervals through the perforations in a rotating disk." Professor Javal, of the University of Paris, was among the first to use the mirror method of direct observation. As early as 1879 he called attention to the fact that the passage of the eye across the page from left to right is discontinuous, consisting of a series of movements and pauses (3). Somewhat later (1891) M. Landolt, also of the University of Paris, made extensive observations by means of the mirror method of direct observation (4). Still later (1897–98) Erdmann and Dodge carried on elaborate investigations at the University of Halle (5). Among the methods used was the mirror method of direct observation. A telescope was also used to advantage.

Meanwhile various mechanical devices were attempted. Lamare, working with Javal, succeeded in attaching a microphone to the upper eyelid which enabled him to count the sounds made by the movements of the eyes and thus to determine in a general way the number of pauses which the eye made in reading a given line (6). Somewhat later (1891) Dr. Ahrens, in studying eye-movements in connection with writing at the University of Rostock, attached an ivory cup to the cornea of the eye. By means of a pointer fastened to the cup he hoped to record on a smoked surface tracings of the movements of the eyes. The attempt, although not successful, was nevertheless suggestive (7). During the year 1897–98 Professor Delabarre, of the Harvard laboratory, resorted, at the suggestion of Dr. Lough, to the use of a plaster-of-Paris cup. This was attached to the cornea of the eye in somewhat similar fashion to that used with Dr. Ahrens' ivory cup. A light thread leading to a recording lever was fastened to the cup. To this lever was attached a thin elastic fiber in such a way that the horizontal movements of the eyes were recorded on the smoked surface of a kymograph cylinder. However, no permanent records of eye-movements were made (8). In the course of the same year Huey, at Clark University, devised, partly at the suggestion of Delabarre, a similar although more perfect apparatus (9). This marked a great step in advance. But, as Dodge points out, the apparatus was not entirely satisfactory. The eye necessarily worked under more or less unnatural conditions because of the

attachment. Moreover, the exactions of the technique were too severe, and the penalties of carelessness too great, to bring the apparatus into general use.

Meanwhile Dodge was at work at Wesleyan University devising a new apparatus. A satisfactory apparatus for recording eye-movements, he held, must necessarily meet the following requirements:

> It must be capable of operating under normal conditions of binocular vision. It must be capable of registering both eyes simultaneously. The unit of measurement must be 1 σ or less. The registering medium may have neither momentum nor inertia, while the eye must perform no extra work during registration and be subjected to no unusual conditions. The apparatus should be such as can be used to record the movements of a large number of eyes without serious inconvenience either during or after the experiments (10).

It appeared to him that photography must ultimately offer the most satisfactory mode of approach. He felt convinced, too, that a pencil of light which had "neither momentum nor inertia, which was absolutely safe and universally available," must constitute the final registering medium. But the development of a technique which would make this possible was no small task. The immediate outcome was an apparatus which enabled Dodge to photograph directly the horizontal movements of the eyes. This method was, however, open to serious objections. "The illumination tended to interfere with the normal eye-movement, the lines of demarkation between pigmented and unpigmented portions of the eye were not sharply defined, and the records could not be satisfactorily enlarged" (11).

After considerable additional experimentation Dodge finally "hit upon the plan of utilizing the eccentric surface of the cornea as a reflector. Instead of photographing the eye directly," he now "photographed the movement of a bright vertical line as it was reflected from the surface of the cornea." The source of the corneal illumination was an arc lamp. The light was first passed through several thicknesses of pot-blue glass, which rendered it highly actinic and of low physiological intensity. Head-movement was eliminated as much as possible by fastening the head securely in a headrest, the latter consisting of an upper-jaw rest, a wooden

nose-bridge, and a mastoid-rest. The pencil of light reflected from the surface of the cornea was focused upon a photographic plate by means of a lens and camera. The plate, which was movable in the vertical plane, was secured within a carefully devised box so that its fall was absolutely constant and all lateral motion was excluded. The time of the eye's movement was recorded upon the falling plate by means of a spring pendulum which vibrated directly behind and at the edge of a horizontal slit in the camera, alternately admitting and excluding the light, and leaving a definite time record on the photographic plate (12).

Naturally the question of the reliability of the records of movements secured on the basis of corneal reflection presented itself. This question Dodge discusses at length, showing that limitations appear only in cases where reflection involves the use of the extreme and peripheral portions of the cornea. Records of reflection from the middle third of the cornea, to which clear vision is limited, are shown to correspond accurately to actual eye-movements (13).

Dearborn, who worked with this apparatus at Columbia University during the year 1904–5, introduced numerous minor modifications, especially by way of perfecting various parts of the technique. He was the first to use the apparatus extensively in experimenting with reading (14). Later on he set up the apparatus at the University of Wisconsin, and still later in the laboratory of the School of Education of the University of Chicago. While connected with the above-named institutions, Dearborn introduced further modifications. By the use of double lenses he was able to secure records of binocular reading. He also experimented successfully with the use of films, the latter being partly suggested by the kinetoscopic studies at Yale.

After Dearborn left the University of Chicago, Dr. F. N. Freeman became interested in the apparatus. He accordingly introduced various minor modifications, perfecting especially the use of the film device. It was at his suggestion, too, that in the course of the present investigation the film device was modified so as to make possible the registration of movements in the vertical plane.

While the Dodge photographic method was being used and perfected, another and in some respects superior method for the study of eye-movements was devised at Yale by Dr. Charles H. Judd, namely, the kinetoscopic photographic method. The Dodge apparatus had certain limitations; eye-movement, for instance, could be measured in only one plane, the horizontal. Dr. Judd overcame this difficulty by using a kinetoscopic camera. This made possible a rapid succession of discrete photographs—eight per second—the records showing the movements of the eye in all planes. Usually a double camera was used so as to get complementary records. The camera was driven by a mechanical device which assured absolutely uniform motion.

In order to get a fixed and identifiable spot on the eyeball—a spot which could be used as a point of reference in the successive photographs—a small particle of Chinese white was placed on the cornea. The photographs, when completed, were projected upon a screen by means of a lantern. By noting the successive positions of the white spot it was possible to measure and chart the varied movements of the eye.

Head-movement was eliminated as much as possible by securing the head in a firm headrest. Iron spectacles with highly polished steel beads fastened to the lower rim were worn by the subject; this made possible a comparison of eye- and head-movement. In order to eliminate error which might result from compensatory eye-movement, the points of reference or fixation were attached to the head, so that they invariably moved with the head. The possibilities of error were thus reduced to a minimum (15).

Since the Yale apparatus made possible the estimation and measurement of movement in the various planes, it was particularly well adapted for a minute study of fixations. McAllister's investigations accordingly dealt in a very thoroughgoing manner with this problem (16). The studies of illusions which were undertaken by Judd, Cameron, Steele, and Courten dealt indirectly with the same problem (17). Judd's final study dealing with convergence and divergence makes important contributions to various phases of the eye-movement problem (18).

2. RESULTS OF EXPERIMENTATION WITH EYE-MOVEMENTS

As previously indicated, up to the time that Huey succeeded in utilizing mechanical registration of eye-movements, the after-image method and the mirror method of direct observation gave the most satisfactory results. These results were, however, quite meager, since the methods were severely limited in several respects. As Dodge says:

> The after-image method was limited to the span of memory, while any after-image sufficiently distinct to be serviceable would be a constant menace to clear vision, and the demands on the attention would more or less disturb the processes it was serving to investigate. . . . . Similarly, the invaluable method of direct observation is limited by the memory span of the observer, and is irregularly interrupted by the pursuit movements of the observing eye (19).

Volkmann and Lamansky were particularly concerned with the estimation of the speed of eye-movement. Their estimates, however, were too low (20). Javal's discovery that eye-movement in reading is discontinuous, consisting of a series of alternate movements and pauses, was of course thoroughly significant. In fact, the chief interest of subsequent experimenters has centered about the nature, function, and relation of these movements and pauses.

a) *Path of the eye's fixation point.*—Erdmann and Dodge were the first to note that the path of the eye's fixation point was not coextensive with the line. The first and last fixations were found to be located within the line—the last more so than the first (21). Huey and Dearborn later confirmed this. The former found that the distance traversed by the eye's fixation point varied from 78 to 82 per cent of the length of the line (22). The latter observed that these indentations varied more or less with individuals and with the nature of end-words (23).

Javal, upon observing on the basis of after-images the prominent part played by the upper part of letters, concluded that the fixation point moved across the line evenly between the middle and the top of the small letters. Huey, with a more perfect technique, noticed that the path of the fixation point was more uneven than Javal had supposed, but concluded that the fixation

point did not wander far above or below the line that was being read (24). Dearborn, detecting on his photographic records indications of considerable movement in the vertical plane, concluded that the path designated by Javal was a "physical impossibility" (25). However, both admit the limitations of their technique. Neither apparatus was capable of registering accurately eye-movements in the vertical plane. The results of the present investigation, the technique of which made such measurement possible, will be referred to later.

b) *Interfixation movements* (26).—Interfixation movements, i.e., the movements of the eye from fixation to fixation, have been studied chiefly from the standpoint of extent and velocity. Javal concluded on the basis of his observations that the extent of these movements was rather uniform. Recent findings, however, have disproved this. Huey and Dodge found that the extent of these forward movements often varied in the ratio of 1:4 (27). Dearborn found the same variation in extent, even though the formation of short-lived motor habits tended to render the number of pauses relatively uniform line after line (28).

The interest of investigators has, however, been centered largely upon the problem of determining the velocity of these movements. The chief question at issue was whether the velocity was such as to condition clear vision. Volkmann and Lamansky, as noted above, were interested in determining the angle velocity of eye-movement, but underestimated it (29). Javal, knowing that the passage of the eye from left to right is discontinuous, attempted by means of after-images to determine the velocity of interfixation movements. Although hampered by the inadequacy of his technique, he concluded that the movement was too rapid to condition clear vision (30). Erdmann and Dodge inferred on the basis of certain calculations that from 12/13 to 23/24 of the time of the eye's passage from left to right was spent in fixations. This velocity was considered too high to admit of significant stimulation (31). Further experimentation on the part of Dodge and Baxt showed that fusion of stimuli was inevitable during interfixation movements (32). Actual measurement of the velocity of these movements by Huey, Dodge and Cline, and Dearborn

gave results which were in general agreement with previous findings (33). There remained, however, one apparent difficulty. In spite of the fact that the conditions were such as to imply fusion, no gray bands were in evidence. This raised the question whether the conditions of fusion might not be different when the eyes, rather than the stimuli, were in motion. If so, perception and orientation might be quite possible during interfixation movements. Experimental evidence in support of this was not entirely lacking (34). However, Dodge presently secured experimental evidence which demonstrated clearly that fusion takes place during these movements (35). Holt likewise concluded on the strength of two experimental proofs that "voluntary movements of the eyes condition a momentary visual central anaesthesia" (36). About the same time Dearborn repeated the calculations of Erdmann and Dodge. He found them substantially correct, and he concluded, therefore, that "the duration of stimulation is well below the threshold necessary for producing a distinct visual impression" (37).

c) The fixation pause.—Significant stimulation is, as we have seen, limited to the fixation pause. This naturally makes the pause the center of experimental interest. It has been studied thus far chiefly from the standpoint of number per line, duration, location, and nature. Javal inferred that there was uniformly one pause to every ten letters (about 5 pauses to a 90 mm. line). Landolt held that on an average 1.55 words were read per pause (about 6.5 pauses to a 90 mm. line). Dodge averaged 5 pauses for an 83 mm. line, and Erdmann 8 for a line of 122 mm. Two of Huey's subjects averaged 4.5 and 4.8 pauses, respectively, for lines 83 mm. in length. With 52 mm. newspaper lines two readers averaged, respectively, 3.4 and 3.8 pauses per line. Dearborn's readers averaged from 3 to 7.1 pauses for somewhat longer newspaper lines, an average of from 1.9 to 1.0 words per pause. For lines not quite double this length from 7.5 to 9.4 pauses were made, averaging from 1.5 to 1.09 words per fixation. Dearborn is the first to stress strongly the fact that great individual variation exists.

The duration of pauses is quite as important a factor as their number. However, since the measurement of the former is a

more delicate task than the estimation of the latter, it is naturally more dependent upon an improved technique. As a result, the data regarding the duration of pauses are very recent. The average for several of Huey's readers appeared to be in the neighborhood of 185 σ per pause. However, his technique was not very well adapted for the measurement of duration. Dearborn was the first to measure duration extensively. His apparatus was such as to insure much greater accuracy. He found in reading the same newspaper passage that five subjects ranged from 160.8 σ (average deviation 36.8) to 401.9 σ (average deviation 163.7). Dearborn found, further, that these differences in duration time were very closely correlated with differences in the rapidity of reading.

Dodge has also devoted considerable attention to the investigation of the duration of pauses, especially as related to reaction time and to the total reading process (38). Although his reaction-time averages fall considerably below the averages for pauses, he feels, nevertheless, that some explanation is needed in the case of the large number of pauses the duration of which either approximates reaction time closely or falls below it. It would be absurd, he states, to attempt to crowd into such brief intervals "the complex apperceptive processes which condition the apprehension of the words as such, their contribution to the sum-total meaning consciousness, and the more or less definite mental and physical reactions to that meaning." "We are forced," he continues, "to postulate a concurrent complication of the psychical processes of perception, extending through several fixations." He suspected, and later demonstrated experimentally, that the long initial pause, which Dearborn had found to be rather common, made possible a general initial survey of the line, and thus modified the duration of succeeding pauses. This, together with constant data from peripheral vision, he concludes, "tends to make the normal reading pause represent a comparatively late moment in the total process of perception."

The fixation pause has also been studied intensively from the standpoint of its location. The chief problem has been to determine with accuracy the location of pauses with respect to syllables,

words, phrases, etc., and to arrive, if possible, at a law governing such location. Erdmann and Dodge's earlier experimentation led them to believe that fixations were centered upon words; in fact, usually upon the middle of words. Later and more accurate measurements by both Dodge and Huey seemed to indicate that the fixation point may be in any part of the word, or even between words. Dearborn, who made the most elaborate study of the location of fixation pauses, comes to similar conclusions. "The exact point that is fixated," he states, "may be in any part of the words, nor does it occur more frequently in the first part of the sentence than in the last, and apparently pays little attention to many of the laws of apperception or the rules of the rhetorician." "The exact object of fixation," he continues, "is significant only as representing the point about which are grouped the 'block' of letters that are simultaneously perceived as one word or phrase complex. It more often falls in the first third than at the center of a given perception area." There were, however, in evidence certain factors which tended to determine the extent of the successive areas, and consequently, in a general way at least, the location of pauses. The perception area was found to be "large in the case of nouns and adjectives and verbs, and usually small in the case of the connective parts of speech, the conjunctions and prepositional phrases, the relative pronouns, the auxiliary verbs" (39). Certain other factors which will be mentioned later on were found to be influential at times in determining the more immediate location of the pauses.

The nature of the fixation pause has further been studied from the standpoint of its steadiness. A careful photographic examination of fixation has shown that the eye is not necessarily at rest during reading pauses. Dearborn found considerable individual variation in this respect. The fixations of some were "precise and relatively steady," while in the case of others fixations and movements were at times indistinguishable. On the whole, however, his records would seem to indicate a rather large amount of shifting during fixation. Dodge likewise found unsteadiness common; so much so, in fact, that he substituted the term "fixation-field" for "fixation-point." However, most of his experimentation

was not concerned with continuous reading. McAllister's study at Yale, "the purpose of which was to determine how the eye behaves when an observer is consciously fixating a point, and how the eye moves from one point of fixation to another," was of course also immediately concerned with this problem. He found that the "eye does not stand still during any period of fixation; that the area of fixation during the successive periods for any point differs in extent and in the relation of the different positions to each other; also that the manner of approach to any point of fixation is not exactly the same for any two periods of fixation" (40). Accordingly, his conclusion is that "the image of a point fixated does not fall upon any particular point of the retina, but may fall upon any point of a considerable area of the retina, round about the fovea centralis"; in other words, "the same elements of the retina are not stimulated during any successive periods of fixation of a point except merely by chance (41). It must be remembered, however, that this experimentation, like that of Dodge, was not concerned with normal reading. In fact, it was limited to the alternate fixation of two points. As will be pointed out later, there are indications that the amount of unsteadiness which characterizes fixations during normal reading has been overestimated. The experimenters in question are agreed, it should be noted further, that the shifting during fixations is too slow to interfere with perception. They are also generally agreed that the shifting does not imply fluctuation of the attention during perception—in other words, that the shifting does not confirm in any way the theories of Wundt and Zeitler. The unsteadiness is accounted for chiefly on the basis of muscular tension.

Dr. Judd's study (42) of simple movements of convergence and divergence between two fixed points has brought to light other very important aspects of eye behavior. Convergence was frequently accompanied by a downward movement of the eyes. Similarly, upward movements were more or less characteristic of divergence. There was also in evidence a certain amount of rotation of the eyeball, in a clockwise direction, in the case of convergence especially. Generally speaking, divergence was found to be a much simpler form of adjustment than convergence. It

was very evident that the two eyes in executing these movements did not as a rule follow paths of the same form, nor did they proceed with the same degree of rapidity. Fixation, however, was not complete until the slower eye had caught up with the other. Dr. Judd attributes these irregularities to "external muscular causes" rather than to "internal nervous adjustments." It was further found that the time of convergent and divergent adjustments is relatively long. The movements themselves appeared complex and difficult, frequent pauses being made by the one eye or the other in passing from one fixation to another. This latter phenomenon, Dr. Judd holds, cannot be explained by "reference to the external muscular structure of the eyes." It would seem to signify rather "that the complete execution of a movement of convergence or divergence is in the nature of a slow and careful adjustment to a stimulus which is in some form or other recognized as not completely met by the main movements." There was in evidence, further, a tendency for the two eyes, before beginning the careful adjustment of convergence, to execute a lateral movement in which both sympathized by moving in the same direction rather than in opposite directions. This lateral movement appeared to be much easier and simpler than those of convergence and divergence. This tendency furnishes undoubtedly strong evidence for the "fundamental and natural character of the sympathetic movement of the two eyes." Similar indications in evidence in the results of the present investigation will be referred to later.

B. TACHISTOSCOPIC EXPERIMENTATION—STUDIES DEALING CHIEFLY WITH THE PERCEPTUAL PROCESS

Valentius was among the first to be interested in perceptual studies in reading. As early as 1844 he found that it was possible to perceive from three to four letters simultaneously in time intervals varying from 100 to 270 σ. He believed, however, that every letter was separately perceived even in the case of the shortest time intervals (43). Exner was interested in the same problem as early as 1868 (44). Baxt followed with an article in 1871 (45). Helmholtz' invention of the tachistoscope greatly facilitated experimentation along this line, since it made possible careful

regulation of exposure time. The results of his own studies were published in 1871 (46). The results of Cattell's extensive experimentation began to appear in 1886. He found that consciousness can on an average grasp "four numbers, three to four letters, two words, or a sentence composed of four words." His conclusions were of course the opposite of those of Valentius. His results indicated that we tend to perceive by word-, phrase-, and sentence-wholes, rather than by successive letters (47).

Goldscheider and Mueller's investigation at Berlin followed presently. The exposure time in this case was limited to one one-hundredth of a second. The materials exposed varied all the way from a group of unrelated strokes to whole sentences. The experimenters found that certain letters and letter groups figured much more prominently in the perception of a word than others. The former letters and letter groups were designated as "determining" and the latter as "indifferent." Consonants and vowels were included in each class. The sight of the "determining" letters and letter complexes, the experimenters concluded, called up the auditory image of the word or group of words, the "indifferent" elements being thus supplied incidentally. The final and significant conclusion of Goldscheider and Mueller was that the perceptual process in reading does not go on either purely by letters or purely by word-wholes, but rather that it varies with conditions, being now by word-wholes and now by letters, according as the material read was more or less familiar (48).

Erdmann and Dodge's experimentation at the University of Halle at a somewhat later date (1896–98) was concerned with the same problem. The method, too, was similar, though the exposure time was longer, namely, one-tenth of a second. The tachistoscopic study was, moreover, supplemented by several other types of investigation. The results led the experimenters to the conclusion that it is the total word-form rather than characteristic letters or letter groups that are fundamental in the perceptual process in reading (49).

Zeitler, at the University of Leipzig, was the next to engage in an elaborate tachistoscopic study. He made more than 6,000 exposures. The exposure time was extremely short, though it

varied slightly with individuals. He agrees with Goldscheider and Mueller in concluding that the perception of words, phrases, etc., is mediated by characteristic letters, and letter and syllable complexes, rather than by total form. He differs with the latter, however, in holding that visual, rather than auditory, imagery aids in completing the perceptual process. Generally speaking, perception in reading involves for Zeitler a very quick succession of conscious processes, the attention moving progressively forward rather than backward and forward (50).

Becker, who a little later engaged in a similar type of experimentation, was chiefly interested in throwing further light upon the problem of the fluctuation of attention during the perceptual process in reading. His findings led him to agree with the conclusions of Erdmann and Dodge, namely, that perception proceeds by word-wholes and phrases, etc., and that fluctuation is absent (51).

Messmer carried on a similar line of investigation at the University of Zurich during the year 1903. He worked, however, with a larger number of subjects than the previous investigators, namely, four adults and six children, the latter ranging in age from six to eleven years. His materials consisted chiefly of words, the exposure time being very short. Generally speaking, his results are in close agreement with those of Goldscheider and Mueller, and Zeitler, i.e., he elaborates the theory of successive perception as mediated by a fluctuation of the attention, and also that of dominating letters and letter complexes. He classifies his readers, however, into two general types, the objective and the subjective. In the case of the former the attention and the fixation point are supposed to coincide closely, the attention fluctuating but little, if at all, its scope being, of course, very narrow. In consequence this type is supposed to perceive successively by combining. The latter type, on the other hand, is supposed to represent a relatively elastic attention, so much so, in fact, that the scope is wide enough to render perception by wholes dominant in the perceptual process in reading. Children, Messmer holds, belong to the latter type almost without exception. They represent a wide fluctuation of attention, and so tend to perceive

prevailingly by wholes. The analysis of determining letters and letter groups is finally greatly elaborated as compared with previous experimenters. Each letter is regarded as having four characteristics: quantitatively there are the factors of height and breadth, and qualitatively those of geometrical form and color. When letters are combined into words, these different characteristics are united into one word-form, the elements in some cases fusing more readily than in others. Breadth in letters is of less significance than height; the latter supplies the characteristic outline, while the former tends to disappear in the total form. Accordingly, Messmer concludes that the tendency toward perception by wholes increases in proportion as the word-forms are characterisic and unitary. The objective type, however, is but little influenced by this consideration (52).

Dearborn's investigations at Columbia University were also incidentally concerned with this problem. His conclusions, however, agree with those of Cattell and of Erdmann and Dodge rather than with those of the other experimenters. His data appear to give "no confirmation to a theory of successive perception of the letters and elements of the word." They point rather to a prevailing tendency toward perception by word-wholes and larger complexes. In this process certain dominating letters and other peculiarities may serve as clues. Beyond this the chief factor is a difference in the span of attention among different individuals. This accounts for the fact that some individuals appear to perceive in larger wholes and complexes than others (53).

Freeman, who more recently engaged in a closely related study at the University of Leipzig, likewise differs with the conclusions of such investigators as Zeitler and Messmer. The primary purpose of Freeman's study was to determine the nature of the span of attention in the case of children. The investigation affords, however, also valuable information regarding the same problem in the case of adults. He found no evidence among either class of subjects to warrant the classifications of Zeitler and Messmer. In fact, the results pointed toward an unusual individual variation, as well as a strong variation under varying conditions. These results are especially significant, since the study involved a much larger

number of subjects than any of the foregoing investigations. There are strong reasons for believing that the conflicting results of the various investigators are due to the persistent tendency to generalize on the strength of too small a number of subjects (54).

C. STUDIES CHIEFLY CONCERNED WITH INDIVIDUAL DIFFERENCES IN SPEED AND COMPREHENSION

One of the earliest significant studies in this field was undertaken by Miss Abell at Wellesley College. Forty-one girls were asked to read a certain selection at home, and to time this reading. At the next class period they were asked to reproduce the story as nearly verbatim as possible. The results showed great individual variation both in speed and in comprehension. The swiftest read more than six times as fast as the slowest. The correlation between speed and comprehension did not appear to be marked, although two of the fastest readers also ranked highest in comprehension. Slow readers, however, appeared to be dominantly of the auditory-motor type (55).

A much more elaborate investigation was undertaken some years later by Dr. Quantz at the University of Wisconsin. Fifty Juniors and Seniors were examined. The chief problem was the rate of reading and its conditioning factors. Accordingly, visual perception was first studied with color, forms, and words. An effort was then made to determine the correlations between visual- and motor-mindedness on the one hand and rate of reading on the other. Quantz found that "forms, colors, isolated words, and words in construction were in ascending order in the rapidity with which they were perceived," the differentiation being most marked in the case of the rapid readers. The greatest variation in the rapidity of perception between the rapid and the slow was in evidence in the case of sentence reading, showing that the rapid reader excels especially in the grasp of connected materials. There was of course also in evidence a high degree of correlation between quickness in perception and rapidity in reading. It was found, further, that the visual type was superior in rapidity to the auditory, while motor-mindedness, as evidenced, for instance, by lip-movement, was a serious hindrance. Finally, the rapid readers

were distinctly superior to the slow in efficiency of comprehension and retention (56).

At a somewhat later date Huey experimented with a number of graduate students at Clark University. He was especially interested in determining maximal and minimal rates in silent and oral reading. He found that in silent reading at the ordinary rate the slow readers averaged 2.5 and the fast 9.8 words per second; at the maximal rate the results were 3.5 and 13.5 words, respectively. In oral reading at the ordinary rate the slow averaged 2.2 and the fast 4.7 words per second; at the maximal speed the averages were respectively 2.9 and 6.4 words per second (57).

Dearborn selected the fastest and the slowest readers from a group of thirty people. He found that the former read silently three times as fast as the latter (58).

More recently a number of rather extensive investigations have been made with the rate and comprehension of the reading of children. Waldo, who examined a large number of children at Sycamore, Illinois, found that there was but little increase in rate beyond the fifth grade, especially in careful reading. Efficiency in comprehension, however, increased progressively from the lowest to the highest grades. The correlation between speed and comprehension was not marked; it was evident, however, that increase in speed does not decrease efficiency in comprehension (59). Oberholtzer recently tested approximately 1,800 children at Tulsa, Oklahoma. His results show a rather progressive increase in speed from grade to grade, the averages being respectively: third grade, 2.3 words per second; fourth grade, 2.6 words; fifth grade, 3.1 words; sixth grade, 3.9 words; seventh grade, 4.7 words, and eighth grade, 4.8 words. There appeared to be a rather close correlation between rate of reading and comprehension, the rapid readers being distinctly superior in their grasp of the content (60). Starch gave reading tests recently to several thousand children. On the basis of the results obtained he computed standard scores of speed efficiency for the various grades. In terms of the number of words read per second these scores are: first grade, 1.5 words; second grade, 1.8 words; third grade, 2.1 words; fourth grade, 2.4 words; fifth grade, 2.8 words; sixth grade, 3.2 words; seventh

grade, 3.6 words; eighth grade, 4.0 words. His results stress in a striking manner individual differences in both speed and comprehension (61). Courtis, who has likewise made extensive investigations in this field, distinguishes in his discussions of results between "normal" and "careful" reading. In the case of the former Courtis found constant improvement in speed efficiency from the lowest to the highest grades, including the high-school period; but in the case of the latter there was no perceptible increase beyond the sixth grade (62). The distinction between normal and careful reading is undoubtedly a most fundamental one. The somewhat contradictory results of some of the investigations which have been reviewed above are most likely, in part at least, due to the fact that most of the experimenters overlooked this distinction. Perhaps the most significant fact stressed by all these studies is that of the existence of an enormous range of individual variation in the efficiency of speed and comprehension in reading.

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CHAPTER III

APPARATUS, METHOD, AND SCOPE

A. APPARATUS

The present investigation was carried on largely by means of a modification of the Dodge photographic apparatus which Dearborn used at Columbia University. The chief departure consists of the substitution of a film-holder device in place of the former falling plate box. This makes possible the registration of eye-movements in both the horizontal and the vertical planes. The apparatus (Diagram I) consists essentially of: the source of light; a time-marker; reflecting mirrors; a headrest; a camera; a film-holder device; and a motor.

1. *The source of light* (*A*).—This is an ordinary arc lamp incased in an asbestos box. The rays are brought to a focus by means of a lens in the front end. The light is further stopped down by blue glass which excludes all but the actinic rays.

2. *The time-marker* (*B*).—This is an ordinary electric time-marker, the vibration rate being governed by a tuning-fork (50 vibrations per second). A light paper flag is fastened to the lever of the marker. The latter is placed in such a position that the flag when vibrating intercepts the light from the arc lamp at the focal point.

3. *Reflecting mirrors* (*C*).—These are one inch square. The reflecting surfaces are silver-plated and highly polished. They are fastened in front, one slightly to the right and the other slightly to the left of the subject's point of regard. The holders are such that the mirrors can be readily adjusted until the light is thrown directly upon the cornea of the reader's eyes, from which it is in turn reflected into the lens of the camera.

4. *The headrest* (*D*).—This furnishes three points of contact, namely: (*a*) a support for the forehead, consisting of a rounded and padded form adjustable in the vertical plane (*E*); (*b*) a set of supports for the temples, consisting of padded forms adjustable

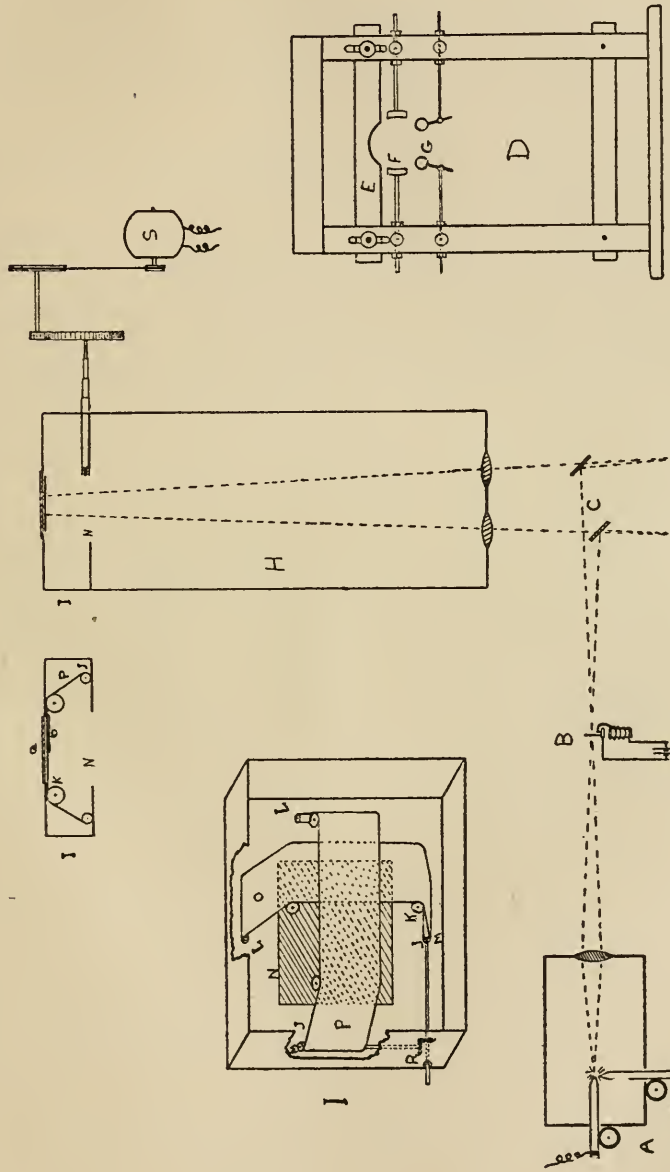

DIAGRAM I

in both the vertical and the horizontal planes (*F*); (*c*) a set of supports for the cheek bones. The latter are essentially round cushions with slightly elastic surfaces, which render them readily adaptable to a variety of features. They are adjustable in both the vertical and the horizontal planes; in addition, they articulate on practically universal joints (*G*).

5. *The camera* (*H*).—This is an ordinary box camera with a long extension bellows. The lenses are adjustable in three planes. This renders them very serviceable.

6. *The film-holder* (*I*).—This holds the films and contains the mechanism by means of which they are kept in continuous motion, the one in the vertical and the other in the horizontal plane. It is essentially a wooden box with a depth of three inches, the other dimensions being the same as those of the camera to which it is fastened. It contains four spool slits, one on each side near the wall (*J*). A steel framework within the box supports four tension rollers, one opposite each spool slit (*K*). In loading the box the full film-spools are inserted into the upper and the right-hand slits (*L*), respectively, while the empty winding-spools are placed into the slits (*M*), situated on the opposite sides. The duplex paper of the full films is then drawn across the tension rollers and threaded into the slits of the empty spools. The tension rollers supporting the vertical film are slightly lower than those supporting the horizontal. This allows the horizontal film to pass over the vertical without friction. The back of the box, which faces the bellows, has an opening through which the rays of light pass in reaching the films (*N*). The rays of light reflected from the left eye are focused upon the vertical film (*O*), and those reflected from the right eye upon the horizontal film (*P*). This makes possible records of eye-movement in both planes, though not of the same eye. However, in more than half of the cases a simpler technique was used, i.e., only the film running in the vertical plane was inserted into the box, the reflections from both corneas being focused upon this. This gave, of course, parallel records of the horizontal movements of the two eyes and afforded a basis for valuable comparison. The finder, consisting of a piece of ground glass, is located in the cover of the box directly opposite the opening in

the back of the box. This is as nearly as possible in the same plane as the films (*Q*). It is, of course, necessary to secure the proper focus of the light-rays before loading the box with the films. The shafts of the two winding-spools are connected by means of bevel gearing, so that both films are driven by the same source of power and at the same speed (*R*).

7. *The motor* (*S*).—The power which moves the films is furnished by an electric motor. This is firmly secured at the left of the camera and the film device. Rotary motion is transmitted by means of a drive-shaft built in sections, one telescoping into the other. This eliminates all lateral vibrations. The rate at which the films move can, of course, be regulated at will by means of the motor; it was, however, kept uniform throughout the main part of the experiment. The films used were regular Eastman Kodak films, $2\frac{1}{2}$ by 42 inches.

B. METHOD

As previously indicated, the Dodge photographic method does not photograph the movements of the eye directly. A more satisfactory medium has been found, namely, a beam of light reflected from the cornea of the eye. That the movements of such corneal reflections are, under normal conditions, substantially true representations of the actual movements of the eyes has been demonstrated by Dr. Dodge (1). The theory underlying the method is "that the virtual images from an eccentrically mounted convex spherical mirror appear to move in the direction of the latter's rotations when its axis lies behind its center of curvature" (2). Since the normal and healthy cornea is, within a very small error, such a convex spherical surface, its reflection appears to move in the direction of its rotation. Dodge discusses in a very critical and thoroughgoing manner the limitations of the method (3). Suffice it to say that the error is inconsequential with respect to the part of the cornea mainly concerned with vision in reading. Toward the periphery the limitations are more pronounced.

The reading took place in a dark room. In order to eliminate head-movements as much as possible, the reader, after being

comfortably seated, had his head firmly secured in the headrest. The reading material was attached to an adjustable framework between the reader and the camera. It was artificially illuminated by means of a screened red light. The actinic rays from the arc lamp were thrown upon the cornea by the silver mirrors, and thence into the lenses of the camera. After the rays from each cornea were brought to a fine focus in the finder, the films were exposed. The reading matter was then uncovered, the films set in motion by means of the motor, and the reader given a signal to begin.

The speed of the motor could be varied, but was constant for any one set of readings, and, in fact, throughout most of the experiment. The length of the reading selections varied, but it rarely exceeded twenty-four lines. All subjects read two selections at a sitting, one orally and the other silently. For the former the subject was instructed to "read so as to be understood," and for the latter to "read rapidly for the thought." The adjustments for any one sitting required more or less time, hence the subject was enabled to accustom himself to the seemingly more or less unnatural circumstances before reading. The actinic light rarely caused discomfort to the subject. When such proved to be the case, the subject was at once dismissed. The consensus of opinion among the subjects was that the technique did not disturb them, and that the reading took place under apparently normal conditions. However, they were nevertheless laboratory conditions, and so may have deviated from the normal more or less; but they were the same for all readers, and so afforded at least a common basis for observation.

The records are, of course, continuous photographs of the movements of the eyes. The film running in the vertical plane recorded the horizontal movements and the one running in the horizontal plane the vertical movements. Since the corneal reflection of the left eye was focused upon the vertical film and that from the right eye upon the horizontal film, the horizontal movements of one eye and vertical movements of the other were recorded. In the majority of cases, however, the corneal reflections from both eyes were focused upon the vertical film some distance apart. Such records represent, of course, only horizontal move-

ments, but they afford on that basis an excellent opportunity for a comparative study of binocular reading.

Since the length of the bellows represents several times the focal length of the lens, the extent of the movements of the eyes is magnified on the records correspondingly. If the light from the arc lamp were not intercepted by the vibrations of the time-marker, the records would be continuous. As it is, they consist of series of dots each representing one-fiftieth of a second. Naturally the records of the movements in the two planes differ widely. If absolutely steady fixations were maintained while the films were in motion, there would appear on each film simply a uniform and straight line of dots, or when both eyes were focused on the vertical film two such lines running parallel. But since reading involves a series of movements and pauses and a return sweep, the records are correspondingly modified. The vertical film which records the horizontal movements of the eyes represents for each pause a vertical line of dots and blanks, and for each movement to the right a slightly diagonal line. The return sweep from right to left is represented by a longer and slightly more diagonal line running in the opposite direction. Irregularities of fixation falling in the horizontal plane are indicated by deviations in the vertical lines of dots and blanks standing for the pauses; similarly, irregularities falling in the vertical plane are roughly indicated by an alternate spreading and crowding of the dots in these lines.

The records on the films running in the horizontal plane are somewhat more complicated. If the behavior of the eyes both in fixation and during movement were steady, a pause would be represented by a straight horizontal line of dots, a movement from left to right by a short gap or stretching out in the line of dots, and the return sweep by a line running nearly parallel to the records of the last few pauses of any one line, the initial pauses of the succeeding line running necessarily also nearly parallel to the latter. Since there is, however, more or less unsteadiness during fixation, the lines of dots and blanks standing for the pauses are wavy rather than straight; the deviations in this case indicate irregularities of fixation falling in the vertical plane, while the

slight alternate spreading and crowding of the dots are indicative of irregularities falling in the horizontal plane.

Since head-movements are probably never entirely eliminated, it was important to determine to what extent these might account for the apparent unsteadiness of fixation. This was made possible by attaching to one end of a pair of spectacle rims, by means of a copper wire, a small but highly polished metal ball. This was adjusted just outside of the left eye in the same vertical plane as the cornea. The light reflected from the polished ball was thus photographed simultaneously with that from the cornea of the right eye. By means of a careful analysis of the records thus obtained it was possible to single out head-movements rather accurately and to compare them with genuine irregularities in fixation.

The interpretation of the records naturally demanded a great deal of attention. The number of pauses per line was easily determined, but the accurate estimation of their duration was a much more difficult task. Since each pause was represented on the records by a vertical line of dots and blanks, each dot and blank standing for one-fiftieth of a second, the number of the latter had to be determined for each pause. This process was facilitated somewhat by the use of a magnifying glass. After the results were reduced to σ, the averages and the average deviations of the number of pauses per line and per selection and the averages and average deviations of the duration of these pauses were carefully computed for each record.

The location of pauses was determined by the method formerly used by Dearborn (4). Immediately before and after the reading of a given passage each subject was required to fixate alternately two points which were even with the ends of the lines. These fixations were represented at the beginning and at the end of the records by two vertical lines connected by a horizontal line, the latter standing for the forward sweep of the eye and consequently for the length of the lines read (90 mm). These initial and final vertical lines were then connected on each side by parallel lines drawn with a fine steel point. The space between the two lines represents the width of the printed page which was read in any

one case. This space on the films was then enlarged by means of a stereopticon lantern until it was identical with the width of the page. It was thus possible to plot on a screen schematically the location of the pauses. By superposition of these schemata upon the respective printed lines it was possible to determine the actual location of the pauses.

Comprehension tests were given to each reader of the elementary- and high-school groups immediately after the selections were read. The tests consisted of a series of carefully graded questions. These were answered in writing in the case of all except the second- and third-grade pupils. In the case of the latter the questions were given orally, and the answers were written by the examiner in the exact words of the subject. The answers were in each case scored with as much precision and uniformity as possible. This method of estimating comprehension, although not entirely free from objections, is nevertheless superior to any other method now in use. In fact, most methods appear to measure little beyond memory for details. Some of these methods seek to determine the index of comprehension on the basis of the "number of words written which correctly reproduce the thought"; others rely chiefly upon the number of detailed ideas reproduced (5). None of these serves the real purpose of reading. Efficient comprehension in reading implies anything but total redintegration or indiscriminate reproduction. On the contrary, it implies careful discrimination—the rejection of the trivial or irrelevant and the selection and emphasis of the significant. The question-and-answer method tends to test this capacity, to say the least. Some form of supplementary test would undoubtedly aid in increasing its efficiency. As it stands, the chief objections to it are: (*a*) that the questions are likely to be suggestive, and (*b*) that the scoring is likely to be subjective. Several more thoroughgoing methods which have recently been developed are unfortunately not as yet readily applicable to the reading of general selections.

C. SCOPE

The scope of this experiment differs materially from those previously undertaken. Investigations thus far have been confined

to a relatively small number of subjects, while other conditions and factors, such as complexity of material, length of line, size of type, etc., have been varied widely. In view of the fact that most recent findings in educational psychology have stressed particularly the prevalence of wide individual variation with respect to practically all capacities and abilities, it appeared to the writer that the interests of the psychology of reading could at the present time be materially furthered by data from a larger and more varied group of subjects. Accordingly, the plans of the present experiment provided, on the one hand, for uniformity with regard to all previously varied conditions, and, on the other, for a larger number of subjects varying in age and accomplishment.

The selection of reading materials presented considerable difficulty. No scientifically standardized selections were available at the time when the experiment was undertaken (autumn of 1913). Two alternatives presented themselves in choosing the selections. One was to use the same uniform simple material or selection for all subjects irrespective of age and accomplishment. Since such materials must necessarily be sufficiently simple so as to fall within the range of the comprehension and reading power of the youngest subjects, there was some question as to the extent to which selections chosen on this basis would constitute an adequate test of adult reading ability. According to the other alternative, several types of material could be chosen, each especially fitted for a specific group representing a definite level of accomplishment, the assumption being, of course, that the selections thus chosen would make nearly equal demands upon the various groups from the standpoint of the ability of each. The latter alternative was chosen. Since there were four distinct groups of subjects, namely, adults, high-school pupils, elementary pupils, and primary pupils, four corresponding types of materials were chosen. An attempt was made by means of careful analyses to choose in each case materials which would make about equal demands upon the capacities of the respective groups. The selections were taken from various sources: the adult group read light passages from James's *Psychology;* the high-school pupils, expository and descriptive passages from Irving's *Sketch Book;* the elementary

pupils, narrative fable passages from the "Riverside Literature Series for Fifth Grade Reading"; and the primary pupils, i.e., the second- and third-grade pupils, very light fable passages from *Fairy Stories and Fables* ("Series of Eclectic Readings for Children"). Two selections of as nearly the same grade as possible were chosen for each group, the one for silent and the other for oral reading.

The materials thus selected for the various groups were further compared by means of several preliminary tests. To begin with, each selection was read silently by two dozen adults, the time being carefully noted. It was interesting to note incidentally that the reading rate of these individuals varied in the ratio of 1 to 3, i.e., the most rapid reader read three times as fast as the slowest. The readers averaged 5 words per second for the adult selection, 5 words per second for the high-school selection, 5.5 words per second for the elementary selection; and 6 words per second for the primary selection. The first two selections evidently made about equal demands upon adult readers; the demands of the third were slightly less, and those of the fourth correspondingly less than those of the third. The first three selections were then compared on the basis of photographic results. Records were secured for the reading of these selections from adult individuals No. 6 and No. 12. The findings are shown in Table I. The final

TABLE I

SHOWING RELATIVE DIFFICULTY OF SELECTIONS

Individual	Selection	Average No. of Pauses	A.D.	Average Duration of Pauses	A.D.	Average Fixation Time per Line	Average No. of Refixations per Line
Adult No. 6	Adult	5.0	0.64	298	92	1,490	1.0
Adult No. 6	Elementary	5.1	0.41	250	72	1,275	0.71
Adult No. 6	High-school	6.0	0.75	258	80	1,548	0.4
Adult No. 12	Adult	5.7	0.40	294	54	1,675	0.13
Adult No. 12	Elementary	5.3	0.60	240	64	1,272	0.18
Adult No. 12	High-school	6.5	0.62	252	48	1,638	0.12

time results, given in terms of σ under "average fixation time per line," are readily comparable with the results of the foregoing test. The relative rank of the selections, it will be observed, is about the

same in both cases. The adult and high-school selections tend to make similar demands in each case, while the elementary selection makes correspondingly lesser demands in both instances. It is not probable that the above figures afford an absolute index to the relative complexity of the selections, simply because the average reader does not read discriminatingly; he tends to read widely varying selections, provided they fall within the range of his experience and comprehension, at a rather uniform rate. Nevertheless, they afford perhaps as accurate an index as is available. To say the least, they enable us to compare the reading capacities of children and adults as well as those of a variety of individuals.

A further analysis of Table I brings out a very interesting and significant fact. Evidently equal time results may be due to varying factors. It will be observed, on the one hand, that the adult and elementary selections make nearly equal demands upon the number of pauses per line, while the demands of the high-school selection are slightly heavier in this respect; on the other hand, in the matter of the duration of pauses the demands of the adult selection are increased and those of the high-school selection decreased, so much so, in fact, that the two selections are placed on the same time level; in the case of the elementary selection, which makes the same demands upon the number of pauses per line as the adult selection, the duration time of the pauses is reduced sufficiently so as to rank its reading time materially below either of the above. Evidently selections may make varying demands upon the number and the duration time of pauses even though the reading time be nearly the same.

In all, records were secured from more than 100 individuals. Only 83 of these were, however, directly concerned with the main part of the investigation, the data from the others being utilized for a variety of accessory purposes. Of the 83 individuals, 45 were adults, mostly graduate and undergraduate students in education and psychology; 17 were high-school pupils, 4 being Freshmen, 4 Sophomores, 5 Juniors, and 4 Seniors; and 21 were grade pupils distributed as follows: 4 from the seventh grade, 6 from the sixth, 4 from the fifth, 3 from the fourth,

2 from the third, and 2 from the second. The subjects were all males.

Since the data for the two types of reading and for the different individuals are largely based on one reading, the question of the reliability of the first reading naturally presents itself. Does such a reading afford a reliable index of an individual's reading capacity? In order to secure data which would throw light upon this question, a number of individuals were required to read several selections of about the same grade. The results of the first reading were then compared with the averages of all the readings. Table II gives the results for adult individuals Nos. 1, 6,

TABLE II

SHOWING RELIABILITY OF FIRST READING

Subject	Kind of Reading	No. of Readings	Average No. of Pauses	A.D.	Average Duration of Pauses	A.D.	Average Fixation Time per Line	Average No. of Refixations
Adult No. 6	Silent	First	5.5	0.50	310	74	1,705	0.50
Adult No. 6	Silent	6	5.1	0.55	307	88	1,565	0.78
Adult No. 1	Silent	First	4.7	0.50	357	72	1,677	0.30
Adult No. 1	Silent	3	4.6	0.44	350	91	1,610	0.40
Adult No. 12	Silent	First	5.7	0.40	294	54	1,675	0.13
Adult No. 12	Silent	4	5.6	0.53	239	51	1,338	0.11
Adult No. 6	Oral	First	7.8	1.10	384	160	2,995	2.60
Adult No. 6	Oral	6	7.4	0.75	398	136	2,945	2.10

and 12 in the case of silent reading, and also for oral reading in the case of individual No. 6. It is evident that there is throughout a slight gain in efficiency as the series of readings progresses, i.e., the time requirements are slightly less in the case of the average of several readings than in the case of the first reading. In some cases this difference is almost trivial, and in no case is it sufficient to invalidate the results of the first reading. Keeping in mind, then, the presence of this slight error, we may regard the results of the first reading as a fairly reliable index to an individual's average accomplishment.

The scope of this investigation was further enlarged by giving comprehension tests to all subjects except those of the adult group. In addition the majority of the records are of binocular reading, i.e., they represent the behavior of both eyes. This, together with

the fact that the apparatus made possible measurement of eye-movement in the vertical plane, will afford valuable psychological data quite apart from pedagogical implications.

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CHAPTER IV

STATEMENT AND DISCUSSION OF RESULTS

A. TABLES, FIGURES, AND CHARTS

The results of this study have been reduced as far as possible to tables, figures, and charts. Since most of the tables represent certain common features, it will be economical to discuss these in general before referring to individual tables. To begin with, the subjects comprising the several groups are ranked in the tables on the basis of the number of pauses which they made in the silent reading of their respective selections, a convenient unit in this case being the average number of pauses per line. This was secured by dividing the total number of pauses made in the reading of a selection by the number of lines in the selection. It is followed in each case by the average deviation, this being determined by dividing the sum of all the deviations by the number of lines in the selection. The individuals are of course ranked in ascending order, those requiring the least number of pauses coming first. In succeeding columns the same facts are given for oral reading. Then follow columns showing the average durations of pauses for both silent and oral reading, the unit of time being the σ. The average duration of the pauses is determined by dividing the sum of the durations of all the pauses in a selection by the total number of pauses in the selection. These are followed in each case by the deviations from the average, the latter being determined by dividing the sum of all the deviations by the number of pauses in the selection. In other columns are given the average fixation times per line for both silent and oral reading. These really represent the reading time per line minus the time spent in interfixation movements and the return sweep. They may be determined by multiplying the average number of pauses per line by the average duration of the pauses in the selection or by dividing the sum of the durations of all the pauses in the selection by the number of lines in the selection. Since the time spent in interfixation movements

and the return sweep is very brief and comparatively uniform, the average fixation time per line affords a very reliable index to rate of reading, and consequently an excellent coefficient for purposes of comparison. Finally, there is a column indicating the average number of refixations per line. The term "refixation" is limited strictly to definite movements to the left, excluding the return sweep, of course. Aside from running in the opposite direction, these refixation movements appear exactly like the interfixation movements on the records. The average number per line is determined by dividing the total number of refixations in the selection by the number of lines in the selection.

There are eleven tables in all. Table I (p. 33) gives the results of one of the preliminary tests, the purpose of which was to estimate the relative difficulty of the adult, high-school, and elementary selections. The comparison is made on the basis of the average number of pauses per line, the average duration of pauses, the average fixation time per line, and the average number of refixations per line. Table II (p. 35) gives the results of the test which was to determine the extent to which the results of the first reading afford a reliable index to a subject's reading capacity. The comparisons are made on the same bases as in the case of Table I. Table III gives the total results for the silent and oral reading of the adult group. The arrangement of the data is such that the two types of reading can be readily compared on the basis of the average number of pauses per line, the average duration of pauses, the average fixation time per line, and the average number of refixations per line. In fact, separate columns show the actual quantitative differences in each case. Tables IV and V present in the same manner the totals for the high-school and the elementary groups, respectively. In addition the last two tables contain the data which make possible comparison on the basis of comprehension. Table VI presents, on the same bases as the above, the total results for the several groups and for their respective subgroups. It is intended to facilitate the comparison of the accomplishments of the different groups. Table VII makes possible a comparison of the three groups on the basis of the average number of pauses per line and the ranges for both silent and oral

Reader	Number of Pauses						Duration of Pauses						Fixation Time			Refixations		
	Silent		Oral		Difference		Silent		Oral		Difference		Silent	Oral	Difference	Silent	Oral	Difference
	Average No. per Line	A.D.	Average No. per Line	A.D.	Average No. per Line	A.D.	Average per Pause	A.D.	Average per Pause	A.D.	Average per Pause	A.D.	Average Time per Line	Average Time per Line	Average Time per Line	Average No. per Line	Average No. per Line	Average No. per Line
1.....	4.7	0.50	6.5	0.50	1.8	0.00	357	72	402	82	45	10	1,677.9	2,613.0	935.1	0.30	1.10	0.80
2.....	5.0	0.44	7.4	0.36	2.4	−0.08	258	78	230	68	−28	−10	1,290.0	1,702.0	412.0	0.10	2.10	2.00
3.....	5.0	0.50	6.6	0.46	1.6	−0.04	428	90	378	104	−50	14	2,140.0	2,494.8	354.8	1.60	1.10	−0.50
4.....	5.0	0.50	9.1	1.10	4.1	0.60	282	86	388	140	106	54	1,410.0	3,530.8	2,120.8	0.80	1.90	1.10
5.....	5.0	0.58	8.4	0.87	3.4	0.29	228	62	380	114	152	52	1,140.0	3,192.0	2,052.0	0.40	2.00	1.60
6.....	5.0	0.64	8.0	0.63	3.0	−0.01	298	92	376	130	78	38	1,490.0	3,008.0	1,518.0	1.00	2.40	1.40
7.....	5.3	0.65	7.0	0.40	1.7	−0.25	270	68	396	140	126	72	1,431.0	2,772.0	1,341.0	0.80	0.90	0.10
8.....	5.3	0.43	6.8	0.32	1.5	−0.11	406	84	464	160	58	76	2,151.8	3,155.2	1,003.4	0.80	1.20	0.40
9.....	5.5	0.80	7.5	0.50	2.0	−0.30	300	72	386	132	86	60	1,650.0	2,895.0	1,245.0	1.50	0.70	−0.80
10.....	5.5	0.64	7.4	0.48	1.9	−0.16	256	64	360	120	104	56	1,408.0	2,664.0	1,256.0	0.43	0.80	0.37
11.....	5.6	0.50	7.7	0.50	2.1	0.00	428	90	504	150	76	60	2,396.8	3,880.8	1,484.0	1.50	1.50	0.00
12.....	5.7	0.40	8.0	1.00	2.3	0.60	294	54	320	90	26	36	1,675.8	2,560.0	884.2	0.13	0.50	0.37
13.....	5.8	0.30	7.4	0.48	1.6	0.18	326	82	400	116	74	34	1,890.8	2,960.0	1,069.2	0.16	0.20	0.04
14.....	5.8	0.40	7.3	0.83	1.5	0.43	302	70	396	86	94	16	1,751.6	2,890.8	1,139.2	0.42	1.50	1.08
15.....	5.8	0.62	7.8	0.50	2.0	−0.12	408	130	520	188	112	58	2,366.4	4,056.0	1,689.6	2.00	3.00	1.00
16.....	5.8	0.70	8.1	1.20	2.3	0.50	308	78	390	160	82	82	1,786.4	3,159.0	1,372.6	1.40	3.10	1.07
17.....	5.9	0.46	7.3	0.40	1.4	−0.06	264	60	380	140	116	80	1,557.6	2,774.0	1,216.4	0.00	1.30	1.30
18.....	6.0	0.57	7.4	0.88	1.4	0.31	248	60	294	88	46	28	1,488.0	2,175.6	687.6	0.40	2.50	2.10
19.....	6.0	0.66	6.5	0.50	0.5	−0.16	268	58	366	136	98	78	1,608.0	2,379.0	771.0	0.20	0.80	0.60
20.....	6.0	0.58	8.1	0.86	2.1	0.28	220	46	312	88	92	42	1,320.0	2,527.2	1,207.2	0.15	2.00	1.85
21.....	6.1	0.25	8.0	0.83	1.9	0.58	310	84	414	126	104	42	1,891.0	3,312.0	1,421.0	1.00	3.50	2.50
22.....	6.1	0.70	8.1	0.99	2.0	0.29	312	90	376	106	64	16	1,903.2	3,045.6	1,142.4	0.80	1.80	1.00
23.....	6.1	0.84	8.5	0.50	2.4	−0.34	272	60	402	152	130	92	1,659.2	3,417.0	1,757.8	0.10	2.00	1.90
24.....	6.1	0.17	8.5	0.75	2.4	0.58	280	74	432	100	152	26	1,708.0	3,672.0	1,964.0	0.62	1.50	0.88
25.....	6.3	0.73	7.6	0.53	1.3	−0.20	370	118	414	112	44	− 6	2,331.0	3,146.4	815.4	0.40	0.40	0.00
26.....	6.5	1.00	9.1	1.10	2.6	0.10	260	70	380	130	120	60	1,690.0	3,458.0	1,768.0	0.00	0.60	0.60
27.....	6.5	0.20	7.2	0.30	0.7	0.10	384	84	376	126	− 8	42	2,496.0	2,707.2	211.2	1.70	1.10	−0.60
28.....	6.5	0.60	7.7	1.30	1.2	0.70	330	70	386	90	56	20	2,145.0	2,972.2	827.2	1.10	1.30	0.20
29.....	6.5	0.60	7.2	0.30	0.7	−0.30	294	62	446	150	152	88	1,911.0	3,211.2	1,300.2	0.50	1.80	1.30
30.....	6.7	0.55	8.6	0.87	1.9	0.32	290	82	432	144	142	62	1,943.0	3,715.2	1,772.2	1.00	1.90	0.90
31.....	6.8	0.30	7.8	0.60	1.0	0.30	324	24	328	78	4	54	2,203.2	2,558.4	355.2	0.00	0.30	0.30
32.....	7.0	0.50	9.2	1.15	2.2	0.65	252	98	336	132	84	34	1,764.0	3,091.2	1,327.2	3.60	3.30	−0.30
33.....	7.2	1.10	9.2	0.68	2.0	−0.42	320	58	376	128	56	70	2,304.0	3,459.2	1,155.2	1.20	0.30	0.90
34.....	7.3	0.90	7.4	0.50	0.1	−0.40	292	90	322	98	30	8	2,131.6	2,382.8	251.2	1.70	1.60	0.10
35.....	7.3	1.30	10.0	1.10	2.7	−0.20	224	102	394	178	170	76	1,635.2	3,940.0	2,304.8	1.30	2.40	1.10
36.....	7.3	1.10	8.2	0.75	0.9	−0.35	326	116	356	108	30	− 8	2,379.8	2,919.2	539.4	1.50	1.60	0.10
37.....	7.4	0.72	8.1	1.40	0.7	0.68	470	68	450	158	−20	90	3,478.0	3,645.0	167.0	1.60	2.60	1.00
38.....	7.6	0.50	9.0	0.50	1.4	0.00	348	72	408	140	60	68	2,644.8	36,72.0	1,027.2	0.30	0.40	0.10
39.....	7.8	0.55	11.2	1.68	3.4	1.13	314	84	340	86	26	2	2,449.2	3,808.0	1,358.8	0.70	1.40	0.70
40.....	8.0	0.00	9.3	1.00	1.3	1.00	214	46	332	114	118	68	1,712.0	3,087.6	1,375.0	0.90	1.70	0.80
41.....	8.2	0.96	10.1	1.15	1.9	0.19	348	112	392	136	44	24	2,853.6	3,959.2	1,105.6	0.54	2.10	1.56
42.....	8.9	1.10	9.1	0.90	0.2	−0.20	294	82	396	130	102	48	2,616.6	3,603.6	987.0	1.20	1.30	0.10
43.....	9.8	1.70	9.8	0.64	0.0	−1.06	376	120	364	114	−12	− 6	3,684.8	3,567.2	−117.6	1.80	2.00	0.20
44.....	10.1	1.60	11.0	0.44	0.9	−1.16	256	62	324	102	68	40	2,585.6	3,564.0	978.4	1.90	2.90	1.00
45.....	10.8	1.15	11.3	0.65	0.5	−0.50	260	112	320	110	60	− 2	2,808.0	3,616.0	808.0	1.50	1.30	−0.20
Average	6.5	0.66	8.2	0.74	1.7	0.08	308.2	78.7	380.8	121.7	72.6	43.0	2,012.4	3,131.5	1,119.1	0.91	1.59	0.68
Per Cent					26	12					23	55			55			74

TABLE IV

Comparison of Silent and Oral Reading—Elementary Pupils

Reader			Number of Pauses						Duration of Pauses						Fixation Time			Refixations			Comprehension	
			Silent		Oral		Difference		Silent		Oral		Difference		Silent	Oral	Difference	Silent	Oral	Difference	Silent	Oral
No.	Grade	Age	Average No. per Line	A.D.	Average No. per Line	A.D.	Average No. per Line	A.D.	Average per Pause	A.D.	Average per Pause	A.D.	Average per Pause	A.D.	Average Time per Line	Average Time per Line	Average Time per Line	Average No. per Line	Average No. per Line	Average No. per Line	Per Cent	Per Cent
1E	7A	13	4.1	0.20	6.1	0.54	2.0	0.34	290	74	372	134	82	60	1,189.0	2,269.2	1,080.2	0.20	1.40	1.20	85	70
2E	2A	8	4.2	0.68	8.3	1.70	4.1	1.02	346	84	472	200	126	116	1,453.2	3,917.6	2,464.4	0.70	2.00	1.30	90	90
3E	4A	10	4.2	0.50	7.2	1.16	3.0	0.66	438	152	386	130	−52	−22	1,839.6	2,779.2	939.6	2.30	1.80	−0.50	80	95
4E	6B	11	4.7	0.54	8.0	1.25	3.3	0.71	300	94	442	186	142	92	1,410.0	3,536.0	2,126.0	1.00	2.00	1.00	65	85
5E	5A	10	4.8	0.43	8.5	1.64	3.7	1.21	316	158	524	280	208	122	1,516.8	4,454.0	2,937.2	1.10	2.50	1.40	80	80
6E	6A	12	5.6	0.47	7.6	0.45	2.0	−0.02	266	72	424	208	158	136	1,489.6	3,222.4	1,732.8	0.10	1.10	1.00	80	80
7E	4A	8	5.6	0.56	7.9	1.00	2.3	0.44	292	114	368	150	76	36	1,635.2	2,907.2	1,272.0	0.70	1.40	0.70	90	90
8E	5A	10	5.9	0.92	6.6	1.66	0.7	0.74	294	90	408	172	114	82	1,734.6	2,692.8	958.2	1.10	1.70	0.60	90	90
9E	7A	12	5.8	0.90	6.5	1.00	0.7	0.10	264	98	340	104	76	6	1,531.2	2,210.0	678.8	2.00	2.00	0.00	90	90
10E	4A	10	6.0	0.50	7.7	0.98	1.7	0.48	360	154	494	250	134	96	2,160.0	3,803.8	1,643.8	1.50	2.70	1.20	65	95
11E	7A	12	6.0	0.66	6.6	1.50	0.6	0.84	346	102	376	100	30	− 2	2,076.0	2,481.6	405.6	0.90	1.50	0.60	85	50
12E	2A	8	6.1	0.60	9.5	1.30	3.4	0.70	350	124	466	172	116	48	2,135.0	4,427.0	2,292.0	1.70	3.50	1.80	90	85
13E	6B	12	6.6	0.90	8.1	1.90	1.5	1.00	334	108	386	148	52	40	2,204.4	3,126.6	922.2	0.50	2.00	1.50	80	00
14E	6A	11	6.7	0.91	8.2	1.04	1.5	0.13	282	70	398	148	116	78	1,889.4	3,263.6	1,374.2	0.70	2.00	1.30	65	95
15E	7A	12	7.1	0.90	7.1	1.10	0.0	0.20	300	84	388	182	88	98	2,130.0	2,754.8	624.8	0.50	0.50	0.00	90	90
16E	6A	....	7.3	0.45	7.3	1.47	0.0	1.02	282	92	394	180	112	88	2,058.6	2,876.2	817.6	0.50	2.50	2.00	80	100
17E	5A	11	7.6	1.60	7.8	1.33	0.2	−0.27	300	128	366	138	66	10	2,280.0	2,854.8	574.8	1.80	3.70	1.90	100	90
18E	6A	12	8.1	1.35	10.0	2.66	1.9	1.31	366	164	408	154	42	−10	2,964.6	4,080.0	1,115.4	4.00	1.90	−2.10	65	95
19E	5A	11	8.2	1.55	10.0	1.65	1.8	0.10	284	92	332	122	48	30	2,328.8	3,320.0	991.2	2.30	2.30	0.00	40	95
20E	3A	9	9.2	1.18	10.3	1.50	1.1	0.32	302	138	300	104	− 2	−34	2,778.4	3,090.0	311.6	2.60	2.60	0.00	70	80
21E	3A	9	9.3	1.90	11.5	2.10	2.2	0.20	282	116	330	180	48	64	2,622.6	3,795.0	1,172.4	1.40	3.70	2.30	75	70
Average.....			6.3	0.84	8.1	1.37	1.8	0.53	314.0	109.4	398.0	163.9	84.7	54.5	1,972.7	3,231.5	1,258.8	1.31	2.13	0.82	78	81
Per Cent.....							28	63					27	50			64			62		

TABLE V

Comparison of Silent and Oral Reading—High-School Students

Reader			Number of Pauses						Duration of Pauses						Fixation Time			Refixations			Comprehension	
			Silent		Oral		Difference		Silent		Oral		Difference		Silent	Oral	Difference	Silent	Oral	Difference	Silent	Oral
No.	Grade	Age	Average No. per Line	A.D.	Average No. per Line	A.D.	Average No. per Line	A.D.	Average per Pause	A.D.	Average per Pause	A.D.	Average per Pause	A.D.	Average Time per Line	Average Time per Line	Average Time per Line	Average No. per Line	Average No. per Line	Average No. per Line	Per Cent	Per Cent
1H	F	14	5.0	0.22	7.2	1.18	2.2	0.96	274	74	512	176	238	102	1,370.0	3,686.4	2,316.4	0.30	3.10	2.80	30	90
2H	J	16	5.3	0.70	7.3	1.60	2.0	0.90	298	98	382	140	84	42	1,579.4	2,788.6	1,209.2	0.90	2.70	1.80	100	00
3H	So	14	5.7	0.60	7.4	0.48	1.7	−0.12	288	90	320	112	32	22	1,641.6	2,368.0	726.4	0.40	0.90	0.50	25	40
4H	F	14	6.0	0.54	7.7	0.70	1.7	0.16	340	94	306	100	−34	6	2,040.0	2,356.2	316.2	0.80	1.00	0.20	60	00
5H	So	15	6.2	1.04	8.6	0.96	2.4	−0.08	238	82	322	136	84	54	1,475.6	2,769.2	1,293.6	1.20	2.00	0.80	25	90
6H	S	16	6.4	0.83	9.1	1.18	2.7	0.35	264	61	322	86	58	25	1,689.6	2,930.2	1,240.6	0.40	1.40	1.00	100	90
7H	J	18	6.7	0.86	9.7	1.80	3.0	0.94	312	102	430	190	118	88	2,090.4	4,171.0	2,080.6	0.60	2.50	1.90	00	30
8H	J	17	6.8	0.60	8.5	1.00	1.7	0.40	320	86	404	142	84	56	2,176.0	3,434.0	1,258.0	0.80	1.50	0.70	90	65
9H	J	16	6.8	0.67	8.6	0.80	1.8	0.13	274	90	320	86	46	− 4	1,863.2	2,752.0	888.8	1.60	1.20	−0.40	60	90
10H	J	17	6.9	0.52	8.8	0.86	1.9	0.34	244	72	326	176	82	104	1,683.6	2,868.8	1,185.2	0.40	1.60	1.20	80	65
11H	So	16	7.5	1.00	8.7	1.10	1.2	0.10	387	120	414	176	27	56	2,902.5	3,601.8	699.3	2.60	2.10	−0.50	50	50
12H	S	18	7.6	1.03	8.9	1.10	1.3	0.07	300	116	366	146	66	30	2,280.0	3,257.4	977.4	1.60	1.90	0.30	60	30
13H	S	19	7.8	0.68	9.3	2.00	1.5	1.32	344	122	360	130	16	8	2,683.2	3,348.0	664.8	1.80	2.00	0.20	60	40
14H	So	15	8.0	0.80	8.2	1.30	0.2	0.50	414	118	458	190	44	72	3,312.0	3,755.6	443.6	1.90	2.40	0.50	100	65
15H	S	18	8.5	1.07	9.0	0.77	0.5	−0.30	340	114	350	134	10	20	2,890.0	3,150.0	260.0	1.10	2.50	1.40	70	100
16H	F	14	9.5	1.57	10.2	1.52	0.7	0.05	302	116	370	166	68	50	2,869.0	3,774.0	905.0	2.30	1.90	−0.40	90	50
17H	F	14	9.6	1.80	8.8	1.17	−0.8	−0.63	350	126	386	138	36	12	3,360.0	3,396.8	36.8	1.80	1.30	−0.50	30	100
Average.....			7.07	0.85	8.6	1.14	1.6	0.29	311.1	98.9	373.4	142.5	62.3	43.6	2,229.7	3,200.4	970.7	1.21	1.88	0.67	60	58
Per Cent.....							23	34					20	44			44			55		

TABLE VI

Comparison of Different Groups and Subgroups

Class of Readers	No. of Readers	Number of Pauses						Duration of Pauses						Fixation Time			Refixations		
		Silent		Oral		Difference		Silent		Oral		Difference		Silent	Oral	Difference	Silent	Oral	Difference
		Average No. per Line	A.D.	Average No. per Line	A.D.	Average No. per Line	A.D.	Average per Pause	A.D.	Average per Pause	A.D.	Average per Pause	A.D.	Average Time per Line	Average Time per Line	Average Time per Line	Average No. per Line	Average No. per Line	Average No. per Line
Elementary group.....	21	6.3	0.84	8.1	1.37	1.8	0.53	314.0	109.4	398.0	163.9	84.7	54.5	1,972.7	3,231.5	1,258.8	1.31	2.13	0.82
Seventh grade.	4	5.7	0.66	6.6	1.03	0.8	0.37	300.0	89.0	369.0	130.0	69.0	41.0	1,731.5	2,428.0	697.3	0.90	1.35	0.45
Sixth grade...	6	6.5	0.61	8.2	1.46	1.7	0.69	305.0	100.0	408.6	170.6	103.6	74.0	2,008.1	3,350.5	1,348.0	1.13	1.91	0.78
Fifth grade...	4	6.6	1.12	8.2	1.57	1.6	0.58	298.5	117.0	407.5	178.0	109.0	61.0	1,965.0	3,330.4	1,365.3	1.57	2.55	0.97
Fourth grade.	3	5.3	0.52	7.6	1.04	2.3	0.52	363.3	140.0	416.0	176.6	52.7	51.3	1,878.2	3,161.4	1,285.1	1.50	1.96	0.46
Third grade...	2	9.2	1.54	10.9	1.80	1.6	0.26	292.0	127.0	315.0	142.0	25.0	49.0	2,700.5	3,442.5	742.0	2.00	3.65	1.15
Second grade..	2	5.2	0.64	8.9	1.45	3.7	0.86	348.0	104.0	469.0	186.0	121.0	82.0	1,794.1	4,172.3	2,378.2	1.20	2.75	1.55
High-school group.....	17	7.1	0.85	8.6	1.14	1.6	0.29	311.1	98.9	373.4	142.5	62.3	43.6	2,229.7	3,200.4	970.7	1.21	1.88	0.67
Senior.....	4	7.6	0.90	9.1	1.24	1.5	0.51	312.0	103.2	349.5	124.0	37.5	20.7	2,385.7	3,171.4	785.7	1.22	1.95	0.73
Junior.....	5	6.5	0.67	8.5	1.21	2.0	0.54	289.6	89.6	372.4	146.2	82.8	58.8	1,878.5	3,202.9	1,324.3	0.86	1.90	1.04
Sophomore...	4	6.8	0.86	8.2	0.96	1.3	0.20	329.5	102.5	378.5	153.5	46.7	51.0	2,332.9	3,123.6	790.7	1.52	1.85	0.33
Freshman....	4	7.5	1.03	8.5	1.14	1.0	0.45	316.5	102.5	393.5	145.0	77.0	42.5	2,409.7	3,303.3	893.6	1.30	1.82	0.52
Adult group....	45	6.5	0.66	8.2	0.74	1.7	0.08	308.2	78.7	380.8	121.7	72.6	43.0	2,012.4	3,131.5	1,119.1	0.91	1.59	0.68

reading. Accordingly, the average number of pauses is given for each of the three groups and for the minimal and maximal individuals in each group. Tables VIII and IX present in the same

TABLE VII

COMPARISON OF GROUPS ON THE BASIS OF THE AVERAGE NUMBER OF PAUSES PER LINE IN BOTH SILENT AND ORAL READING

CLASS OF READERS	NO. OF READERS	SILENT READING			ORAL READING		
			RANGE			RANGE	
		Average No. of Pauses per Line for Group	Average for Individual Making Least No. of Pauses per Line	Average for Individual Making Largest No. of Pauses per Line	Average No. of Pauses per Line for Group	Average for Individual Making Least No. of Pauses per Line	Average for Individual Making Largest No. of Pauses per Line
Adults.....	45	6.5	4.7	10.8	8.2	6.5	11.3
High-school pupils	17	7.0	5.0	9.6	8.6	7.2	10.2
Grade pupils.....	21	6.3	4.1	9.3	8.1	6.1	11.5

manner and for the same purpose the data for the average duration of pauses and for the average fixation time per line, respectively. Table X brings out on a percentage basis for the three groups

TABLE VIII

COMPARISON OF GROUPS ON THE BASIS OF THE AVERAGE DURATION OF PAUSES IN BOTH SILENT AND ORAL READING

CLASS OF READERS	NO. OF READERS	SILENT READING			ORAL READING		
			RANGE			RANGE	
		Average Duration of Pauses for Group	Average Duration of Pauses for Minimum Individuals	Average Duration of Pauses for Maximum Individuals	Average Duration of Pauses for Group	Average Duration of Pauses for Minimum Individuals	Average Duration of Pauses for Maximum Individuals
Adults.....	45	308.2	214	470	380.8	230	520
High-school pupils	17	311.1	244	414	372.9	306	512
Grade pupils.....	21	314.0	264	438	398.0	300	524

the excess expenditure in oral reading as compared with silent, the bases of comparison being average number of pauses per line, average duration of pauses, average fixation time per line, average number of refixations per line, and average deviations. Table XI

TABLE IX

Comparison of Groups on the Basis of the Average Fixation Time per Line in Both Silent and Oral Reading

Class of Readers	No. of Readers	Silent Reading			Oral Reading		
		Average Time per Line for Group	Average Time per Line for Minimum Individuals	Average Time per Line for Maximum Individuals	Average Time per Line for Group	Average Time per Line for Minimum Individuals	Average Time per Line for Maximum Individuals
Adults.....	45	2,012.4	1,140.0	3,684.8	3,131.5	1,702.0	4,056.0
High-school pupils	17	2,229.7	1,370.0	3,360.0	3,200.4	2,356.2	4,171.0
Grade pupils.....	21	1,972.7	1,189.0	2,964.6	3,231.5	2,210.0	4,454.0

TABLE X

Showing Percentage of Excess Expenditure in Oral Reading Compared with Silent Reading

Class of Readers	No. of Readers	No. of Pauses per Line	A.D.	Duration of Pauses	A.D.	Average Time per Line	Refixations
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Adults.....	45	26	12	23	55	55	74
High-school pupils	17	23	34	20	44	44	55
Elementary pupils	21	28	63	27	50	64	62

TABLE XI

Correlations

Class of Readers	Silent and Oral	Silent Reading			Oral Reading		
	Between Average No. of Pauses	Between Average No. and Average Duration of Pauses	Between Average No. of Pauses and Total Fixation Time per Line	Between Average Duration of Pauses and Total Fixation Time per Line	Between Average No. and Average Duration of Pauses	Between Average No. of Pauses and Total Fixation Time per Line	Between Average Duration of Pauses and Total Fixation Time per Line
	$r =$	$r =$	$r =$	$r =$	$r =$	$r =$	$r =$
Adults.....	0.693 ± 0.051	-0.004	0.660 ± 0.057	0.552 ± 0.084	-0.023	0.681 ± 0.053	0.546 ± 0.070
	$r =$	$r =$	$r =$	$r =$	$r =$	$r =$	$r =$
High-school pupils	0.634 ± 0.097	0.590 ± 0.103	0.904 ± 0.020	0.737 ± 0.073	-0.0008	0.612 ± 0.101	0.941 ± 0.018
	$r =$	$r =$	$r =$	$r =$	$r =$	$r =$	$r =$
Elementary pupils	0.505 ± 0.108	0.012	0.920 ± 0.031	0.290 ± 0.133	-0.0038	0.823 ± 0.047	0.397 ± 0.115

shows the correlations between: the average number of pauses in silent and in oral reading, the average number of pauses per line and the average duration of pauses for both silent and oral reading, the average number of pauses per line and the average fixation time per line for silent and oral reading, and the average duration of pauses per line and the average fixation time per line for both types of reading. The Pearson formula for determining the coefficient of correlation was used.

Figs. 1–4 represent the distributions of the three groups for both silent and oral reading, Figs. 1 and 2 showing the distributions on the basis of the average number of pauses and Figs. 3 and 4 those on the basis of the average duration of pauses. Since the groups vary in size, the frequencies were all reduced to percentages. In order to bring out possible tendencies due to the grade rank of pupils, the positions of the subjects in the high-school and elementary groups are indicated within the frequencies of their respective distributions, the former being designated by Roman numerals, I standing for Freshmen, II for Sophomores, etc., and the latter by Arabic, 2 standing for second grade, 3 for third, etc. On this basis Fig. 1 shows the distributions with respect to the average number of pauses per line in silent reading, the class interval being one pause. Fig. 2 gives the same distributions for oral reading. Fig. 3 shows the distributions on the basis of the

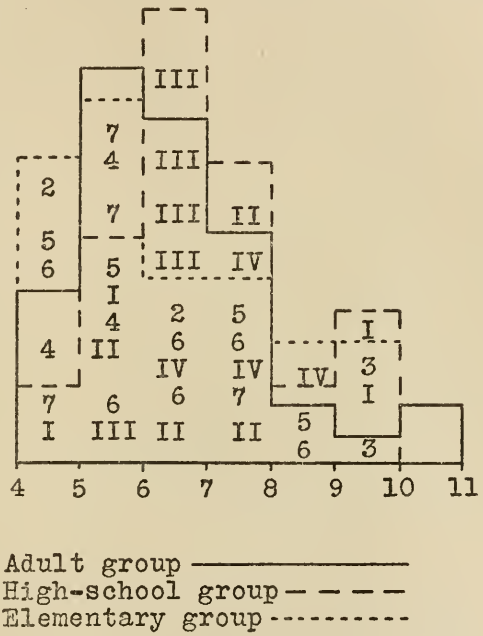

FIG. 1.—Distributions on the basis of the number of pauses. Silent reading.

average duration of pauses for silent reading, the class interval being in this case 50 σ. Fig. 4 gives the same distributions for oral reading. Fig. 5 shows the distributions on the basis of the average perception time per line for both types of reading.

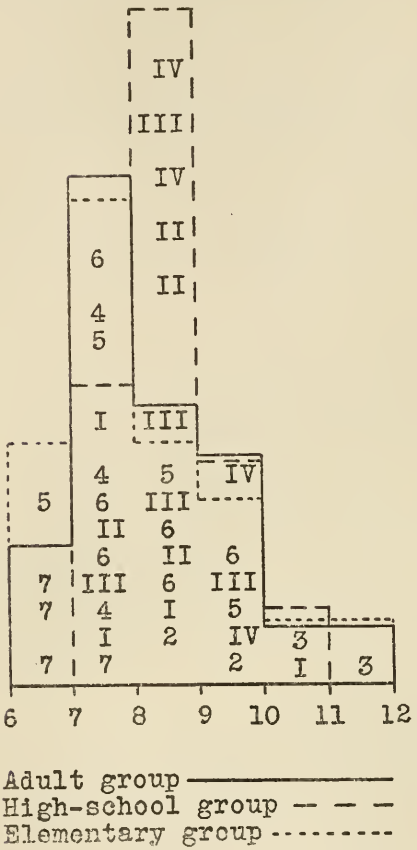

FIG. 2.—Distributions on the basis of the number of pauses. Oral reading.

Charts I–III (pp. 50–52) show the location of pauses in both silent and oral reading for representative individuals of the three groups. Three individuals represent each group, one making a minimal, one an average, and one a maximal number of pauses per line. The location of the pauses within the lines is indicated by dots over the lines. The dots represent merely the initial point of location; shifting during pauses has been estimated, but is not recorded on the charts. It should be noted further that the location of the dots shows merely the horizontal position of the fixation pauses, no attempt having been made to locate these with reference to the height of words or letters.

B. FIXATION PAUSES

Erdmann and Dodge, as previously indicated, early came to the conclusion that from 12/13 to 23/24 of the total reading time was spent in pauses. This conclusion has since been generally substantiated, so much so, in fact, that the fixation pause is now

without exception regarded as the only period of significant stimulation. A certain amount of indirect vision may be present during movement, but this serves largely purposes of orientation. This being the case, the fixation pause must necessarily constitute the point of departure in investigations of this kind. Accordingly, our interest centers about the pause, its nature, number, duration, and location.

1. *Nature of fixation pauses.*—As stated above, the pause is the period of significant stimulation. This does not mean, of course, that the pause itself is limited to clear vision. Both Dodge and Dearborn hold that it involves indistinct or peripheral vision quite as much as distinct or central vision. The former particularly holds that peripheral vision plays a very important part in the reading process. Not only does it serve purposes of general orientation, but it affords "premonitions of coming words and phrases, as well as a consciousness of the relation of the immediately fixated symbols to the larger groups of phrase and sentence. Without this premonition of coming words and the outlines of larger groups the process of reading would be slow and difficult." At times this indistinct vision may even condition actual reading.

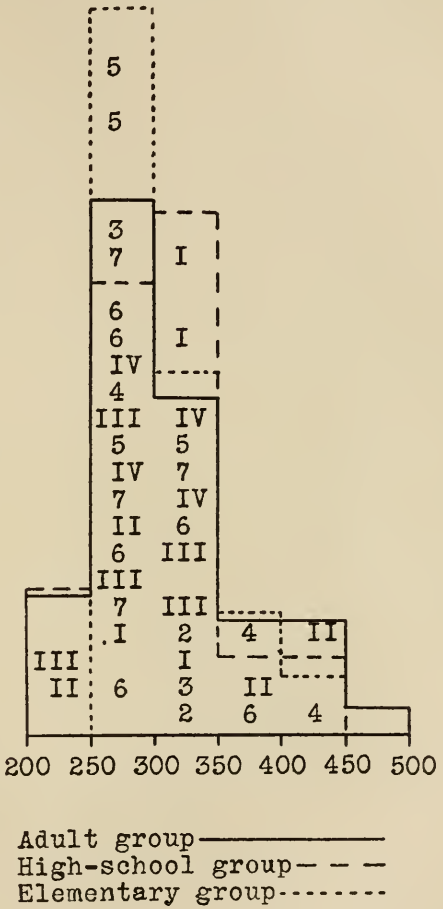

FIG. 3.—Distributions on the basis of the duration of pauses. Silent reading.

The moment of clear vision, on the other hand, is for Dodge "an incident somewhere in the middle of the reading process. Coming between the premonition and the after-echo, its effect is to correct, to confirm, and to intensify the premonition. Psychologically, its function is selective and definitive. It emphasizes the excitation

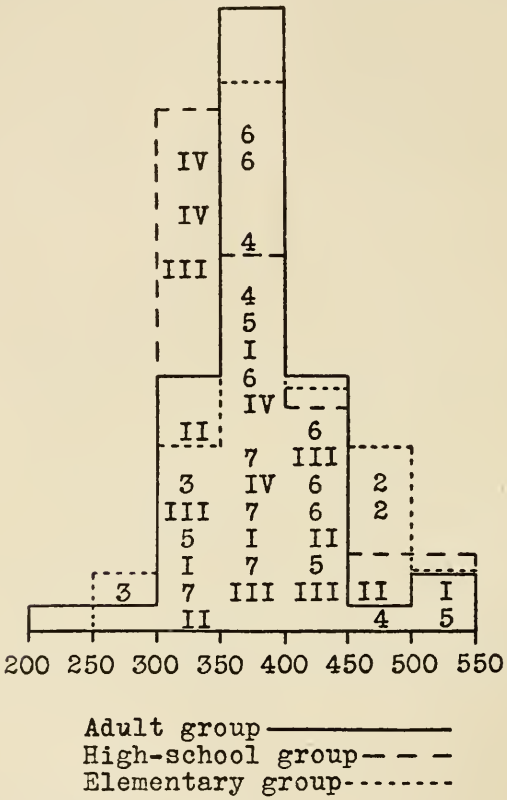

FIG 4.—Distributions on the basis of the duration of pauses. Oral reading.

of suitable residua and inhibits the misfits" (1). Dearborn's views are similar, though he has not elaborated them as much. He accounts, for instance, for the somewhat longer initial pauses in the case of each line by assuming that the eye makes at this time a general survey of the whole or of a part of the line (2). As will be pointed out later, the length of the initial pauses, in so far

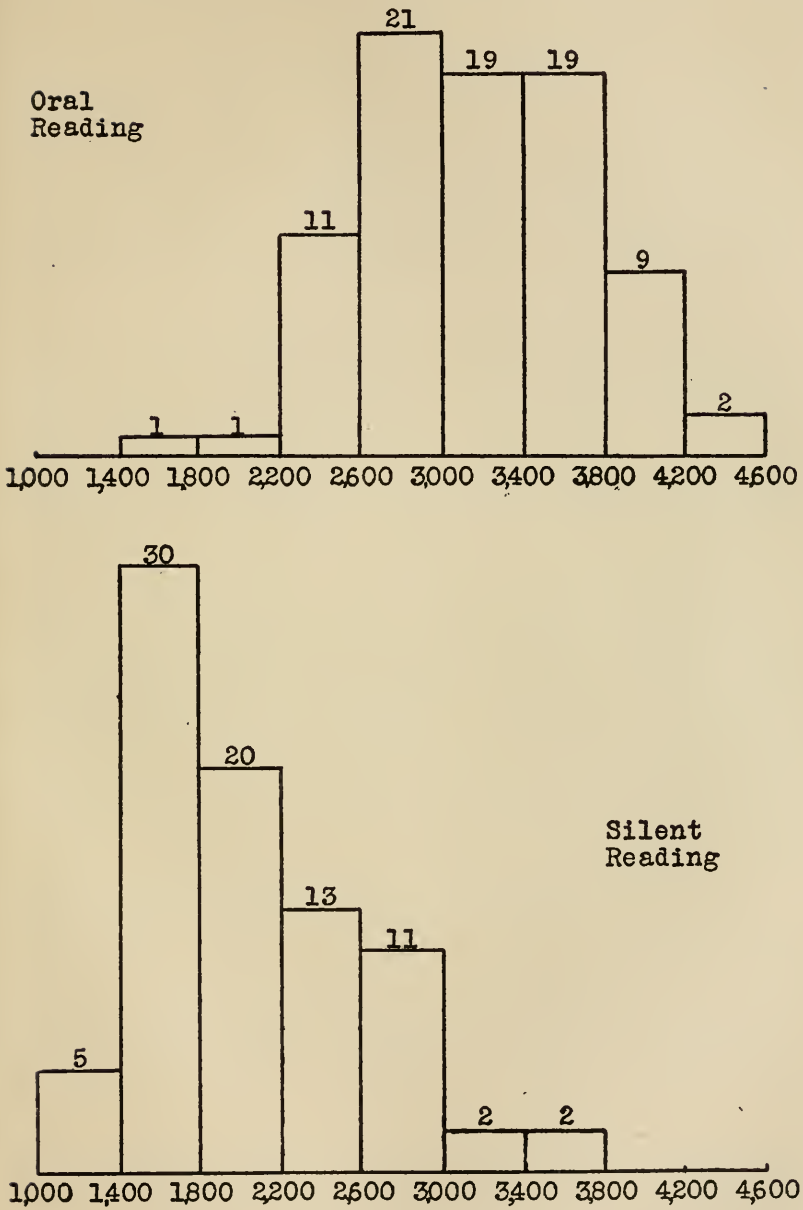

Fig. 5.—Distributions for silent and oral reading on the basis of perception (or reading) time.

LOCATION OF PAUSES IN SILENT AND ORAL READING

SILENT—ADULT NO. 3 C. AVERAGE, 5 PAUSES

The selection of a particular hole to live in, of a particular mate, of a particular feeding-ground, a particular variety of diet, a particular anything, in short, out of a possible multitude, is a very widespread tendency among animals, even those low down in the scale. The limpet will return to the same sticking-place in the rock, and the lobster to its favorite nook on the sea-bottom. The rabbit will deposit its dung in the same corner; the bird makes its nest on the same bough. But each of these preferences carries with it an insensibility to other opportunities and

SILENT—ADULT NO. 11 C. AVERAGE, 7 PAUSES

The selection of a particular hole to live in, of a particular mate, of a particular feeding-ground, a particular variety of diet, a particular anything, in short, out of a possible multitude, is a very widespread tendency among animals, even those low down in the scale. The limpet will return to the same sticking-place in the rock, and the lobster to its favorite nook on the sea-bottom. The rabbit will deposit its dung in the same corner; the bird makes its nest on the same bough. But each of these preferences carries with it an insensibility to other opportunities and

SILENT—ADULT NO. 19 C. AVERAGE, 10.8 PAUSES

The selection of a particular hole to live in, of a particular mate, of a particular feeding-ground, a particular variety of diet, a particular anything, in short, out of a possible multitude, is a very widespread tendency among animals, even those low down in the scale. The limpet will return to the same sticking-place in the rock, and the lobster to its favorite nook on the sea-bottom. The rabbit will deposit its dung in the same corner; the bird makes its nest on the same bough. But each of these preferences carries with it an insensibility to other opportunities and

ORAL—ADULT NO. 3 C. AVERAGE, 8 PAUSES

Leaving lower animals aside, and turning to human instincts, we see the law of transiency corroborated on the widest scale by the alternations of different interests and passions as human life goes on. With the child life is all

ORAL—ADULT NO. 11 C. AVERAGE 9.2 PAUSES

Leaving lower animals aside, and turning to human instincts, we see the law of transiency corroborated on the widest scale by the alternations of different interests and passions as human life goes on. With the child life is all

ORAL—ADULT NO. 19 C. AVERAGE, 11.3 PAUSES

Leaving lower animals aside, and turning to human instincts, we see the law of transiency corroborated on the widest scale by the alternations of different interests and passions as human life goes on. With the child life is all

CHART I

as they are longer than the rest, is in all probability conditioned by necessary motor adjustments. This fact, however, does not preclude the possibility of a more general incidental survey of the

SILENT—HIGH-SCHOOL INDIVIDUAL NO. 1. AVERAGE, 5 PAUSES

The stranger who would form a correct opinion of the English character must not confine his observations to the metropolis. He must go forth into the country; he must sojourn in villages and hamlets; he must visit castles, villas, farmhouses, cottages; he must wander through parks and gardens;

SILENT—HIGH-SCHOOL INDIVIDUAL NO 11. AVERAGE, 7.5 PAUSES

The stranger who would form a correct opinion of the English character must not confine his observations to the metropolis He must go forth into the country; he must sojourn in villages and hamlets, he must visit castles, villas, farmhouses, cottages; he must wander through parks and gardens,

SILENT—HIGH-SCHOOL INDIVIDUAL NO. 15 AVERAGE, 8•5 PAUSES

The stranger who would form a correct opinion of the English character must not confine his observations to the metropolis He must go forth into the country; he must sojourn in villages and hamlets, he must visit castles, villas, farmhouses, cottages; he must wander through parks and gardens,

ORAL—HIGH-SCHOOL INDIVIDUAL NO. 1. AVERAGE, 7•2 PAUSES

Those who are in the habit of remarking such matters must have noticed the passive quiet of an English landscape on Sunday. The clacking of the mill, the regularly recurring stroke of the flail, the din of the blacksmith's hammer, the whistling of the ploughman, the rattling of the cart, and all

ORAL—HIGH-SCHOOL INDIVIDUAL NO. 11. AVERAGE, 8.7 PAUSES

Those who are in the habit of remarking such matters must have noticed the passive quiet of an English landscape on Sunday. The clacking of the mill, the regularly recurring stroke of the flail, the din of the blacksmith's hammer, the whistling of the ploughman, the rattling of the cart, and all

ORAL—HIGH-SCHOOL INDIVIDUAL NO. 15. AVERAGE, 9 PAUSES

Those who are in the habit of remarking such matters must have noticed the passive quiet of an English landscape on Sunday. The clacking of the mill, the regularly recurring stroke of the flail, the din of the blacksmith's hammer, the whistling of the ploughman, the rattling of the cart, and all

CHART II

line during such fixations. In fact, motor adjustments go hand in hand with perception in connection with all fixation pauses. It would be quite fallacious, however, to attribute the premonition of which Dodge speaks entirely to indirect vision, or to vision in

general, for much of it comes undoubtedly from the context. The reader is, as it were, immersed in the meaning of that which is being read, be it the sentence, the paragraph, or the selection. Without such cues indirect vision would be seriously handicapped. As it is, the two undoubtedly go hand in hand.

SILENT—ELEMENTARY INDIVIDUAL NO. 6. AVERAGE, 5.6 PAUSES

There was once a man who had three sons, and nothing else in the world but the house in which he lived. Now each of the sons wished to have the house after his father's death; but the father loved them all alike, and did not know what to do; he did not

SILENT—ELEMENTARY INDIVIDUAL NO. 10. AVERAGE, 6 PAUSES

There was once a man who had three sons, and nothing else in the world but the house in which he lived. Now each of the sons wished to have the house after his father's death; but the father loved them all alike, and did not know what to do; he did not

SILENT—ELEMENTARY INDIVIDUAL NO. 16. AVERAGE, 7.3 PAUSES

There was once a man who had three sons, and nothing else in the world but the house in which he lived. Now each of the sons wished to have the house after his father's death; but the father loved them all alike, and did not know what to do; he did not

ORAL—ELEMENTARY INDIVIDUAL NO. 6. AVERAGE, 7.6 PAUSES

One summer morning a little Tailor was sitting on his table by the window; he was in good spirits, and sewed with all his might. There came a woman down the street crying, "Good jams cheap! Good jams cheap!"

ORAL—ELEMENTARY INDIVIDUAL NO. 10. AVERAGE, 8.8 PAUSES

One summer morning a little Tailor was sitting on his table by the window; he was in good spirits, and sewed with all his might. There came a woman down the street crying, "Good jams cheap! Good jams cheap!"

ORAL—ELEMENTARY INDIVIDUAL NO. 16. AVERAGE, 7.3 PAUSES

One summer morning a little Tailor was sitting on his table by the window; he was in good spirits, and sewed with all his might. There came a woman down the street crying, "Good jams cheap! Good jams cheap!"

CHART III

A discussion of the nature of the fixation pause necessarily involves the question of the nature of the behavior of the eye during fixation. How does the eye behave during fixation? Does it move freely or is it held in absolute position? While the whole question of the behavior of the eye during the reading

process will be discussed in a later chapter, the main facts, at least as far as they concern the behavior of the eye during fixation, may be anticipated at this time. As previously noted in the historical résumé, Dodge, McAllister, and Dearborn came to the conclusion that the eye was by no means always at rest during fixation; in fact, the first two felt that it was generally in motion. However, their conclusions were based upon a study of fixations in isolation, that is, apart from regular reading. It was accordingly significant to note that Dearborn, whose study involved fixations as found in actual reading, discovered great individual variation, some subjects maintaining remarkably steady fixations, while those of others appeared equally unsteady. Some of the unsteadiness, too, was in all probability due to head-movement, since it was not possible to exclude the latter entirely or to distinguish it clearly from eye-movement. And at best the number of subjects in the case of each of the foregoing experimenters was too small to warrant final conclusions. At any rate, the results of the present investigation show that the majority of the individuals tend to maintain remarkably steady fixations during normal reading. Many of the irregularities which seemed at first to indicate eye-movement are clearly due to head-movement, and possibly in rare cases to slight vibrations of the apparatus. By securing records simultaneously of head-movement and eye-movement, the former by means of photographic records of light reflected from a highly polished metal ball fastened to one end of a pair of spectacle rims, and the latter by the usual process of photographing light reflected from the cornea during actual reading, and, further, by securing independent records of possible vibrations of the apparatus by photographing light reflected from points of reference on the apparatus, it was possible to analyze the regular reading records and to single out the several components, such as vibrations of the apparatus, head-movement, and eye-movement. The results show that vibrations of the apparatus were practically non-existent, while head-movements were quite common. In fact, a large proportion of the irregularities and deviations on the records is clearly due to head-movement. Deviations involving a gradual change in direction in the case of the vertical lines of

dots and blanks standing for the fixation pauses represent the most common type of eye-movement, namely, the type involving convergent adjustment. It is most clearly in evidence in the case of the initial fixation pauses of each line, though it is by no means limited to these pauses. As will be pointed out in the next chapter, all rapid eye-movements, such as are involved in the interfixation movements and the return sweep, are accompanied by divergence, and all fixation is accompanied by some degree of convergence. These adjustments involve eye-movement in both planes, the horizontal and the vertical. They account for the bulk of eye-movement during fixation, the type of eye-movement which is the very essence of the motor adjustment conditioning the perceptual process. Two minor types of eye-movement will also be discussed, the one representing a more elementary type of eye-movement than that which is involved in divergent and convergent adjustment, and the other being indicative of a slight unsteadiness of the eyes during fixation.

2. *Number of pauses.*—Dearborn was the first to note that the number of pauses required for the reading of a given line or a given selection is subject to great individual variation. His subjects averaged from 3.0 to 7.1 pauses per line in reading the same newspaper passage. The results of the present investigation are quite as striking in this respect. In fact, individual variation is so much in evidence that other factors, such as age and training, sink into comparative insignificance. The wide variations are evident at a glance. The individual averages range in the case of silent reading from 4.1 to 10.8 pauses, and in the case of the oral from 6.1 to 11.5 pauses per line.

The first six columns of Tables III–V give all the data regarding the number of pauses for the three groups, individual averages being included. Figs. 1 and 2 show the distributions of the groups on the basis of the number of pauses per line. The facts in each case indicate that the wide ranges referred to above cannot be accounted for on the basis of extreme stray individuals, since the distributions aside from being skewed approximate normality. In the case of silent reading (Fig. 1) the distributions are all skewed toward the extreme representing the large number of pauses.

The same tendency is evident in the distributions for oral reading (Fig. 2), particularly in the case of the adult and the elementary groups, the high-school group showing in this instance a narrower range and somewhat greater uniformity. Although these distributions, especially those of the high-school and elementary groups, are based on too small a number of subjects to warrant final inferences, there are nevertheless in evidence certain tendencies which would in all probability not be materially affected by an increase in numbers. The fact that there is, with but one exception, only one interval or class beyond the modal class at the extreme representing the small number of pauses indicates undoubtedly that there is a rather definite limit, physiologically and psychologically determined, below which the number of pauses cannot be readily reduced in reading lines of a given length and complexity. A great many individuals evidently tend to approximate this limit. The persistent tendency of the skew toward the end representing the large number of pauses, as well as the accompanying tendency toward wide dispersion, indicates that there is room for much greater variation on this end than on the former. In other words, although individuals cannot read lines of a given length and complexity without making a certain minimal number of pauses, they may vary greatly above this, some requiring an exceptionally large number of pauses. This has reference, of course, to normal reading at either average or maximal speed, normal reading being defined as the type of reading in which the subject reads the successive words and lines without skimming. The reading in this investigation was, as will be pointed out later, average or careful normal reading. Individual variation in the number of pauses is no doubt conditioned chiefly by two factors, physiological and psychological limitations on the one hand and individual habits on the other. Tachistoscopic experimentation has shown clearly that the field of clear vision and the span of attention are subject to great individual variation. There is reason to believe that there is a close correlation between such variation and variation in the number of pauses. Similarly, a careful questioning of the adult subjects in this investigation has brought out the fact that reading habits vary widely. Many

subjects appear to have remained almost entirely unconscious of the reading process. They read naïvely, as it were, their reading habits having been determined by circumstantial and chance factors. Such readers rarely approach the natural limits referred to above. Some readers, on the other hand, appear to be thoroughly conscious of the reading process. In fact, their present reading habits are the result of conscious direction. Such readers frequently approach very closely the limits set by their natural capacities. It is safe to say, however, that this latter class is distinctly in the minority.

The number of pauses made in the reading of a given line naturally determines the amount read per fixation; the fewer the number of pauses the larger will be the number of words read, and vice versa. Dearborn's readers, it will be recalled, averaged for silent reading in the case of the newspaper line from 1.9 to 1.0 words per fixation. In the present investigation the adult subjects average for silent reading from 2.15 to 0.93 words per fixation, the high-school students from 2.04 to 1.04 words, and the elementary pupils from 2.44 to 1.04 words. For oral reading the averages for the same groups vary respectively from 1.52 to 0.87 word, from 1.39 to 0.98 word, and from 1.62 to 0.86 word. It is evident that there is in this respect a close agreement between the results of the two studies.

Column 1 of Table XI shows that there is a rather high correlation between the number of pauses in silent and in oral reading. In other words, an individual is likely to occupy a somewhat similar rank in the number of pauses which he requires for silent and oral reading. This might imply on the one hand the domination of a common capacity, and on the other the domination of a common habit. It is difficult to tell which figures more prominently. If habit is the chief factor, conscious improvement in the rate of reading ought to change the correlations. That this may actually happen at times is shown by the fact that the more rapid and conscious readers show a lesser degree of correlation. Such readers make, of course, a greater distinction between the number of pauses for silent and for oral reading than do the slower. In the case of oral reading the possibilities for improvement are limited; hence the change in correlation.

Table XI indicates, further, that there is a very high correlation between the average number of pauses per line and the total perception time per line. In the case of silent reading the correlations for the adult, high-school, and elementary groups are, respectively, 0.660±0.057, 0.904±0.020, 0.920±0.031. For oral reading the corresponding figures are, respectively, 0.681±0.053, 0.612±0.101, 0.823±0.047. Pause rank is evidently a very strong factor in determining speed efficiency in both silent and oral reading.

3. *Duration of pauses.*—The average duration of pauses is subject to about as much individual variation as is their number. Dearborn found that the averages for four of his readers in the case of the newspaper column ranged from 160.8 to 401.9 σ. The complete individual averages as well as the averages for the groups in the case of the present study are given in columns 7–12 inclusive of Tables III–V. In addition, Table VIII shows the averages and ranges for the three groups. The averages for the groups, it will be noticed, approximate each other closely. This is true for both silent and oral reading. The wide ranges between the averages of the minimal and maximal individuals in each group are evident at a glance. In silent reading the adults vary from 214 to 470 σ, the high-school students from 244 to 414 σ, and the elementary pupils from 264 to 438 σ. In oral reading the ranges are even wider, the averages for the adults ranging from 230 to 520 σ, those for the high-school students from 306 to 512 σ, and those for the elementary group from 300 to 524 σ. It should be noticed, however, that these ranges are somewhat more influenced by a few exceptional individuals at the extremes than in the case of silent reading. This is shown by the individual data in Tables III–V, and also by the distributions of the groups as represented by Figs. 3 and 4, Fig. 3 giving the distributions for silent and Fig. 4 those for oral reading, the class interval being 50 σ. It is interesting to note that these distributions tend to be skewed in the same direction as the distributions for the number of pauses (Figs. 1 and 2). The skewness in each case is toward the maximal extreme. There are, however, two exceptions, namely, the distribution for the high-school group in the case of silent reading (Fig. 3) and the distribution of the adult group in the case of oral

reading (Fig. 4). On the whole, however, there appears to be in the case of the duration of pauses, as in the case of their number, a rather well-defined lower limit which tends to be approximated by a considerable number of individuals. At the other extreme more variation is in evidence in both cases.

While the results regarding the duration of pauses are in general agreement for the different groups of the present investigation, it is evident that they differ from Dearborn's findings as quoted above. Not only is his range (from 160.8 to 401.9 σ) materially wider, but his maximal and minimal averages are considerably lower. In fact, his duration times appear to be lower all around. The short maximal duration might be accounted for by the fact that Dearborn's data are derived from a small group of subjects, but this does not account for the wider range, nor for the shorter minimal average, and, least of all, for the all-around shorter duration times. A comparison of the materials used in the two investigations shows that they do not vary sufficiently to account for the discrepancy. The technique, apparatus, and methods used in measuring the duration times were not only very similar in the two experiments, but they were so carefully devised and so well controlled as to preclude error from that source. Evidently the explanation must be sought elsewhere. It is significant to note to begin with that Dearborn's minimum duration averages are very low when compared with the reaction time of the eye as determined by Huey and Dodge. Huey found a visual reaction time of 206.9 σ (A.D. 20.7 σ) (3). Dodge quotes averages varying from 151.0 σ (M.V. 9.9 σ) to 181.0 σ (M.V. 19.1 σ) (4). With one exception these reaction times exceed Dearborn's minimum duration averages. As both writers indicate in their discussions, it is quite possible that the duration of pauses may at times fall below the normal reaction time of the eye because of the heightened readiness for the stimulus, the latter being due, of course, to preparatory peripheral perception and to implications from the context. It is not probable, however, that all the pauses or even the average of the pauses in a given selection would be shorter in duration than the reaction time of the eye. If such cases do occur, one would expect them in connection with excep-

tionally rapid reading. A comparison of Dearborn's results on the basis of the number of words read per second with the results of other experimenters shows clearly that his readers were either exceptionally rapid readers or that they read at a maximal speed during the experiments. His minimal subject T shows, in the case of the newspaper lines, an average duration time of 160.8 σ, the average number of pauses per line being 3.7. This gives an average fixation or reading time per line of 594 σ. With an average of 7.1 words per line, the reading rate (in terms of the number of words per second) amounts to 11.7 words per second. On the same basis his maximal (slowest) subject averages 3.2 words per second (5). Quantz found that his subjects averaged in normal silent reading from 3.5 to 8.8 words per second; for reading at maximal rate the averages ranged from 3.5 to 12.2 words per second (6). Similarly, Huey's subjects averaged in normal silent reading from 2.5 to 9.8 words per second and in silent reading at maximal rate from 3.5 to 13.5 (7). Starch, who tested approximately 10,000 elementary pupils, arrives at a standard score of 4.0 words per second for eighth-grade pupils (8); Oberholtzer found an eighth-grade average of 4.8 words per second (9); and the eighth grades in the Norman public schools, tested by the writer, averaged 4.4 words per second. In the present experiment the subjects average from 2.7 to 8.7 words per second (see adult subjects Nos. 5 and 43). Dearborn's figures, it will be noticed, correspond closely to both Quantz's and Huey's figures for silent reading at maximal rate; the figures for the present investigation, on the other hand, approximate very closely the averages for normal silent reading as given by Quantz and Huey. Similarly, the averages for the groups, being in this case 5.15 words per second for the adults, 4.56 words per second for the high-school pupils, and 5.1 words per second for the elementary pupils, correspond closely to the averages for the eighth grades referred to above. The conditions under which the grade tests were given were such as to command normal rather than maximal reading; the subjects in each case knew that they were to be tested for comprehension of materials read as well as for speed of reading. While the subjects in the present experiment were not specifically

directed to read either at normal or at maximal speed, it is very evident that they read at a normal rather than at a maximal rate. In fact, the conditions really implied normal reading. The reader was told to read rapidly for the thought; while not all adult subjects were given comprehension tests, they understood, nevertheless, that they were subject to such tests. Consequently, meaning was emphasized rather than speed, the result being careful reading at normal rather than maximal rate. This accounts very largely for the difference in the duration of the pauses in the case of the two investigations. Rapid reading, as distinguished from normal or careful reading in the case of any one individual, appears to be conditioned by shorter duration of pauses rather than by a reduction in the number of pauses. That such is the case is brought out very clearly by the last four pairs of records of Plate I. The first record of each pair represents rapid reading and the second careful reading. It is very evident that the records differ chiefly with respect to the duration of pauses, the durations in the case of the first record of each pair being materially shorter than that of the second. It should not be inferred, however, that rapid readers as a class are such because of short durations rather than because of economy in the use of pauses. Both are important factors in producing speed efficiency in reading. In cases where a momentary increase in speed is to be effected, a reduction of the duration of the pauses appears to be the chief contributing factor. Whether this is also true in cases where the rate of reading is gradually increased by practice, or whether there is a corresponding reduction in the number of pauses going hand in hand with the reduction in the duration of the pauses, is an interesting question which is as yet unsolved.

The fifth and eighth columns of Table XI show the correlations between the average duration of pauses and the average fixation or perception time per line. In the case of silent reading these are 0.552 ± 0.084 for the adult group, 0.737 ± 0.073 for the high-school pupils, and 0.290 ± 0.133 for the elementary pupils; in connection with oral reading the corresponding averages are 0.546 ± 0.070, 0.941 ± 0.018, and 0.397 ± 0.115, respectively. The correlations are quite marked in the case of the adult and the

high-school groups for both types of reading, showing that there is a positive relationship between rank in average duration of pauses and rank in speed of reading. In the case of the elementary group this relationship is not as strongly in evidence, possibly, in part at least, because the duration factor does not appear to be as well perfected in the case of children as in the case of older individuals.

4. *Perception (or reading) time.*—The average perception time per line is of course the product of the average number and the average duration of pauses. It is essentially the reading time minus the time required for interfixation and return movements. Since it constitutes all but a small fraction of the total reading time, and is further practically the only variable in reading time, the time consumed in movements being relatively constant, it furnishes a very reliable index to efficiency in the speed of reading. Columns 13–15 of Tables III–V give the individual and group averages for both types of reading; Table IX shows the averages and ranges for the three groups. The averages for the groups are in the case of silent reading 2,012.4 σ for the adults, 2,229.7 σ for the high-school students, and 1,972.7 σ for the elementary pupils. In other words, the average perception time for a line of ten words was nearly two seconds in the case of the elementary group and a little over two seconds in the case of the adult and high-school groups. Expressed in terms of the number of words read per second, the results for the three groups are, respectively, 4.9, 4.5, and 5.1 words. In the case of oral reading the perception times for the same groups are, respectively, 3,131.5 σ, 3,200.4 σ, and 3,231.5 σ; in terms of the number of words read per second the results are, respectively, 3.2, 3.12, and 3.08 words. These results, assuming that the time consumed in movements would not introduce much change, agree very closely with Huey's findings. Twenty of his subjects, when reading at normal rate, averaged for silent and oral reading 5.63 and 3.55 words, respectively (10).

On the basis of the number of words read per second the ranges for the adult, high-school, and elementary groups extend in the case of silent reading, respectively, from 8.68 to 2.71 words, from 7.3 to 2.98 words, and from 8.49 to 3.34 words; and in the case

of oral from 5.88 to 2.46 words, from 4.24 to 2.39 words, and from 4.52 to 2.24 words, respectively. It is evident that the most rapid silent readers tend to read approximately three times as fast as the slowest, while the most rapid oral readers read twice as fast as the slowest. This again is in close agreement with previous findings. Dearborn's most rapid silent readers read three times as fast as the slowest. Huey's twenty subjects averaged in normal silent reading from 2.5 to 9.8 words per second; in oral reading the averages ranged from 2.2 to 4.7 words per second.

5. *Location of pauses.*—As previously indicated, approximately one-half of the records were examined for the purpose of determining the location of pauses. Dearborn's elaborate investigation, it will be remembered, brought him to the conclusion that the fixation pause may be located "in any part of the words, or in the spacing between them, that it does not fall predominantly in the first part of the words, nor more frequently in the first part of the sentence than in the last," and that it "apparently pays little attention to many of the laws of apperception or the rules of the rhetorician." He concludes, further, that the "short connective and non-substantive words and the prepositional phrases and relative clauses make the greatest demands upon perception"—nouns, verbs, adjectives, familiar phrases, and rather long words requiring relatively slight attention. This means, of course, that the size of the apperceptive unit will vary in accordance with the predominating type of words. To a certain extent the precise location of pauses would thus be governed by chance since the varying size of the apperceptive unit would place it now here and now there; however, Dearborn holds that this is by no means always the case, for the exact location may "in part depend on the more or less artificial peculiarities of spacing, punctuation, and the forms of letters in printing," and in part on the fact that "within certain limits the eye can regulate its positions in order to maintain its so-called 'short-lived motor habits'" (11).

Charts I–III show the location of the pauses in the case of typical individuals from the present study. These illustrations include records from a rapid, a medium, and a slow reader of each group, both silent and oral reading being represented. Only

the initial position of the pauses is indicated; the shifting of the fixation point in either direction was recorded in the measurements, but is not represented here.

It is evident from the charts that the pauses may be located in almost any part of the words and even in the spaces between them. Location in spaces is, however, comparatively rare. In fact, it is much less in evidence than in the case of Dearborn's charts. When it does occur, it serves almost invariably a group of two or more words which constitute a unit of perception. Note, e.g., Silent, Adult No. 3 C, line 4, "even those low down"; Silent, Adult No. 11 C, line 6, "in the same"; Silent, High-School No. 1, line 1, "the stranger," and line 4, "he must"; and Silent, Elementary No. 16, line 2, "the sons." That location in spaces should be rare is on the whole to be expected, since the spaces constitute a relatively limited portion of any given line. Pure chance would tend to render such location infrequent. Moreover, the printed word acts undoubtedly as a stimulus, and in so doing increases the proportion of pauses falling within the words.

The results indicate, further, that slightly more pauses tend to fall within the last than within the first part of words. The difference is, however, in all probability too small to be of much significance. Of greater importance, no doubt, is the fact that locations near the center of words are much more common than those at either one of the extremes. In some cases nearly half of the words are thus centrally located. Note, e.g., Silent, Adult No. 3 C, line 6, "will deposit its dung in the same corner; the bird makes," and lines 7 and 8, "carries with it an insensibility to other opportunities and"; Silent, Adult No. 11 C, lines 6, 7, and 8, "its nest . . . . opportunities and"; Silent, Elementary No. 6, lines 1, 2, and 3, "There was . . . . have the house"; and Silent, Elementary No. 10, lines 1 and 2, "There was . . . . in which he." While this is particularly true in the case of rapid silent reading, it is more or less in evidence for most readers and for both types of reading. In the case of the rapid readers this is undoubtedly due, in part at least, to the fact that such readers rarely fixate words twice, the result being naturally a reduction in the number of end fixations. Other causes are in all

probability also operative. For instance, we are in the habit of viewing most familiar objects as units, to begin with at least. There are, of course, unlimited possibilities for analysis and abstraction, but these processes require time. There is every reason to believe that a familiar word-form would tend to be viewed as a unit. In fact, the tendency to perceive or read by word wholes has been amply demonstrated by extensive tachistoscopic experimentation. Other things being equal, such perception would favor central fixation. There are, of course, many interfering factors which will be referred to presently. It is highly probable, too, that meaning would tend to condition central location of pauses, using the term "central" especially with reference to the apperceptive unit, whether this be one or several words. As Dodge points out so fittingly, the moment of actual fixation represents a comparatively late stage in the total reading process. The reader is more or less conscious of that which has gone by and of that which is to come. He is, as it were, being swept on by the flow of thought or meaning. Aided, further, by immediate context and by peripheral vision, he singles out significant words or phrases. That he should tend to fixate such units centrally is altogether in accordance with expectation. The attraction of phrase and word-form referred to above would, of course, favor this tendency. However, as indicated, there are undoubtedly many distracting factors. Among these are defective motor control, as well as tendencies toward the formation of short-lived motor habits; peculiarities of word-form, unusual letter complexes, and strange word combinations demanding analysis; and punctuation. The influence of motor factors has been amply discussed by Dearborn (12). It is highly probable, however, that the influence of motor habits is distinctly subordinate to the influence of word-form and meaning, especially in the case of developed or rapid reading. In the very nature of the case such reading must be a consciously controlled rather than a habitual process. Of course, habit undoubtedly plays its part. We may designate readers in certain cases as habitually slow or as habitually rapid quite irrespective of their intrinsic reading potentialities. However, there is every reason to believe that efficient reading is controlled rather by conscious

ideals and consequently by discrimination, making possible constant adaptation to materials of varying complexity. The other interfering factors mentioned above, namely, peculiarities of word-form, unusual letter complexes, and strange word combinations, undoubtedly play a considerable part in determining precise locations of pauses. These peculiarities interrupt the normal flow of the reading process because they demand special attention and analysis. As a result, they not only frequently determine the precise location of pauses, but they increase the number of pauses and also lengthen their duration at times. The prevalence of these factors would naturally vary greatly with the complexity of reading materials. In the case of simple selections, such as were used in the present investigation, they would not be strongly in evidence. However, reference to the charts will show that they are not entirely lacking. Finally, it must be admitted that the demands of perception appear in many cases to be met quite as adequately by a fixation near either end of the apperceptive unit as by one centrally located.

On the whole, the words within which the pauses fall do not appear to belong predominantly to any one class. This is, of course, particularly true in the case of the medium and the slow readers who average in many cases little more than one word per pause. This is naturally even more in evidence in the case of oral than in the case of silent reading. The records of adult individual No. 19 C represent the extreme in this case. Few words escape direct fixation in this instance and many of the longer words are fixated twice. The words which escape fixation are short and of the type which combine readily with others to form units. The records of high-school individual No. 15 and elementary individual No. 16 show similar tendencies. In the case of the more rapid readers whose averages approximate from 1.5 to 2 words per pause there is in evidence a distinct tendency to fixate the longer words and to fixate these but once. This does not imply that no short words are fixated. Quite a number are, as a matter of fact. However, other things being equal, the short word is much more likely to escape fixation than the long. This is particularly true of the short word which combines readily with

others to form units of perception. The words thus omitted may belong to almost any class, the most common being pronouns, prepositions, short adjectives, and auxiliary verbs.

C. COMPARISON OF GROUPS

One of the main purposes of the present investigation was to characterize the reading process of individuals at various stages of development. Accordingly, the individuals who served as subjects varied greatly in age and accomplishment, ranging all the way from second-grade pupils to college students and professors. There are, to begin with, three well-defined groups, namely, adults, high-school students, and elementary pupils. The last two may be conveniently subdivided for purposes of comparison. The high-school group represents four distinct subgroups, one for each of the four classes. Similarly, the elementary group subdivides itself readily into six classes, one for each of the grades from the second to the seventh inclusive. Table VI gives the totals for these groups and subgroups, and Figs. 1 and 2 show the distributions of the individuals within the groups.

1. *Number of pauses.*—The three main groups approximate each other closely in the number of pauses which they require in the reading of a given length of line. This is true for both silent and oral reading. In the case of the former the elementary group represents the smallest number of pauses, the adult group averaging 0.2 of a pause more and the high-school group 0.7 of a pause more; the same relative ranking obtains in the case of the latter, the adult group averaging 0.1 of a pause more than the elementary and the high-school group 0.5 of a pause more. The slight excess of the high-school group is to be accounted for, as previously indicated, by the fact that the selections read by this group made relatively more demands upon the group than did the other selections upon the other groups. The close approximation of the three groups is, to say the least, very striking. It shows very clearly that individuals, after having once mastered the technique of reading, tend on an average to require about the same number of pauses in reading a given length of line quite irrespective of age and accomplishment, provided, of course, that the reading material falls within the range of their comprehension. This,

however, does not in any way preclude the prevalence of marked individual variation.

An examination of the subgroups in the case of the elementary and high-school groups shows very clearly that the factor to be reckoned with is individual variation rather than variation due to age and accomplishment. In the case of silent reading there is no correlation whatever between grade rank and efficiency in the use of pauses. The second, fourth, and seventh grades require the least number of pauses, while the sixth, fifth, and third require the largest number. The same thing is true for the high-school group, the Juniors and Sophomores showing the lowest averages and the Seniors and Freshmen the highest. Practically the same situation obtains in the case of the oral reading. The seventh and fourth grades represent the least number of pauses and the fifth, sixth, second, and third the largest number. In the case of the high-school group the Sophomores require the least number of pauses and the Seniors the largest. The fact that marked individual variation prevails is further emphasized by Figs. 1 and 2, which show the distributions of the individuals within the groups, the former for silent and the latter for oral reading. The Roman numerals indicate the positions of the individuals of the high-school group, I standing for Freshmen, II for Sophomores, III for Juniors, and IV for Seniors. The Arabic numerals 2–7 indicate the positions of the pupils of Grades 2–7 inclusive. In neither case is there any evidence of a general age or grade tendency.

One characteristic, however, demands our attention. The exceptionally high averages of the second and third grades in the case of oral reading are in all probability quite significant, especially when we take into consideration the fact that the second grade required the least number of pauses in silent reading. While the number of subjects representing these two grades is too small to warrant definite conclusions, the results tend, nevertheless, to show pretty clearly that this stage represents a period in individual development when the mechanism which controls the complex process of oral reading has not, as yet, been fully established. The fact that these two grades differ, on the other hand, so radically in the number of pauses which they require for silent reading leads to the suspicion that the mechanism which controls silent reading

may likewise be, as yet, very loosely established in the case of some individuals of this period, even though it is in the case of other individuals thoroughly perfected. In other words, it is highly probable that this period represents a more or less critical transition stage in the mastery of the reading process, a stage during which the individual succeeds gradually in passing from slow word-reading to more rapid thought-getting as far as silent reading is concerned, and a stage during which the individual gradually gains control of the exceedingly complex mechanism of oral reading. It is highly probable that the appearance and duration of this transition stage may vary materially with individuals, being completed in some cases before the second grade, and continuing in others beyond the third grade.

2. *Duration of pauses.*—The three main groups approximate each other quite as closely in the duration of reading pauses as they did in their number. The advantage lies, however, in this case with the adult and high-school groups rather than the elementary group. The durations of the several subgroups vary quite a little in some instances, but these variations, as in the case of the number of pauses, do not appear to be correlated with age or grade rank. The distributions of the individuals within the groups, as shown in Figs. 3 and 4, confirm this conclusion. The most significant difference brought out by these comparisons is the fact that the elementary group requires longer pauses for both types of reading than does the adult group. This reverses the relationship which obtained in the case of the number of pauses. All in all, the facts in the case point rather strongly to the conclusion that the processes of adjustment involved in fixation have not been as thoroughly perfected in the case of children as in the case of adults.

3. *Perception (or reading) time.*—Since the main groups approximate each other so closely with respect to both the number and the duration of pauses, there is necessarily but little variation in their perception-time averages. The adult group occupies second rank in silent reading and first in oral; the elementary group, first in silent and third in oral; and the high-school group, third in silent and second in oral. The difference between the perception times of the elementary and adult groups is too small to be sig-

nificant. In the case of the high-school group the difference is more marked, but not significantly so, since the selection read made somewhat heavier demands upon the readers. On the other hand, the fact that the elementary group ranks first in silent and only third in oral reading points to the conclusion that children have not mastered the technique of oral reading as well as that of silent.

Since there appeared to be no correlation between age and grade rank on the one hand and the number and duration of pauses on the other, there is naturally no correlation in evidence between age and grade rank and perception time. Table VI illustrates this very clearly. In the case of the elementary group Grades 7, 2, and 4 occupy the highest ranks in the perception time of silent reading, while Grades 7 and 4 occupy a similar rank in the perception time of oral reading. In the case of the high-school group the Seniors and the Freshmen represent the longest duration times for silent reading and the Juniors and Freshmen for oral reading. Correlation with age and grade rank is thus as little in evidence in the case of perception time as it is in the case of the number and the duration of pauses. This fact, coupled with the further fact that the perception-time averages of the three groups approximate each other very closely, shows pretty definitely that efficiency in speed of reading must be accounted for on the basis of other factors than age or grade rank. While the number of children representing each of the several grades is of course too small to warrant final conclusions, the results indicate, nevertheless, rather clearly that age has very little to do with the speed of reading, even in the case of children, after they have once passed the transition stage and have mastered the technique of reading, provided the reading materials fall within the range of their comprehension. This at once raises the question: To what extent do the results of recent tests of the speed of reading support this conclusion?

Unfortunately these investigations were made under very different conditions, so that the results vary materially in some instances. However, general tendencies are in evidence. Starch computed, on the basis of the results obtained from tests given to several thousand pupils, standard scores of efficiency for each grade.

In terms of the number of words read per second these scores are: first grade, 1.5 words; second grade, 1.8 words; third grade, 2.1 words; fourth grade, 2.4 words; fifth grade, 2.8 words; sixth grade, 3.2 words; seventh grade, 3.6 words; eighth grade, 4.0 words (13). Oberholtzer, who tested approximately 1,800 children, quotes the following averages: third grade, 2.3 words; fourth grade, 2.6 words; fifth grade, 3.1 words; sixth grade, 3.9 words; seventh grade, 4.7 words; eighth grade, 4.8 words. His conclusion is that "there seems to be a definite correlation of the rate of reading among the grades, the rate of silent reading increasing most rapidly as the grade is advanced" (14). The results of tests which the writer recently gave to approximately 800 children in the Norman (Oklahoma) schools are as follows: third grade, 2.2 words; fourth grade, 2.6 words; fifth grade, 3.6 words; sixth grade, 3.9 words; seventh grade, 4.1 words; eighth grade, 4.4 words. Courtis, upon testing the speed of normal silent reading of 1,469 individuals ranging from fourth-grade pupils to adults, quotes approximately the following median scores: fourth grade, 2.6 words; fifth grade, 3.0 words; sixth grade, 3.7 words; seventh grade, 4.2 words; eighth grade, 4.3 words; adults, 5.3 words (15). The results of the foregoing tests show practically without exception a strong tendency toward correlation between age and grade rank and speed of reading, and so stand apparently in opposition to the tendency supported by the results of the present investigation.

The results of several other investigations point, however, in quite a different direction. Waldo, who made extensive tests in the Sycamore (Illinois) schools, found but little increase in the reading rate after the fifth grade; there was, however, a progressive increase with the grades in the quality of comprehension (16). The results of tests given by the writer to the pupils of the Elementary School of the University of Chicago show that the average of the seventh grade surpasses that of the fourth grade by only 0.23 word per second. Courtis, who gave tests for careful silent reading to 1,478 individuals ranging from fourth-grade pupils to adults, found the following median scores: fourth grade, 1.7 words; fifth grade, 2.2 words; sixth grade, 2.9 words; seventh grade, 3.0 words; eighth grade, 3.3 words; adults, 3.0 words. Careful

reading differed from normal reading chiefly by the fact that it was followed by tests for comprehension. Accordingly, Courtis' conclusion is that the normal reading rate continues to increase until the high-school years, but that the rate of careful reading is practically constant from the sixth grade on (17). The results of extensive tests recently given by Gray to 1,831 pupils in the Cleveland schools and to 2,654 pupils in thirteen other cities show the same general tendency. The Cleveland pupils show in the case of silent reading very rapid improvement from the second to the fourth grades, the score of the former being nearly 2.0 words and that of the latter about 3.6 words. From the fourth to the eighth grades the improvement is very slow, amounting to only about 0.6 of a word. The pupils from the thirteen other cities likewise show very rapid improvement from the second to the fourth grade, the score of the former being about 1.6 words and that of the latter 3.0 words. From this point on improvement in speed is comparatively slow, the eighth grade exceeding the fourth by only 1.0 word. The results of the careful comprehension tests, which accompanied the tests for rate of reading, show that comprehension tends to improve much more gradually and continuously (18). It is quite evident that the results of the studies which have just been enumerated are in rather close agreement with the results of the present investigation. In other words, the results support the conclusion that the speed of reading, under certain circumstances at least, does not vary materially after the individual has passed the critical transition stage and has thoroughly mastered the technique of reading.

Our next problem is to determine the conditions which account for the difference in the results in the case of the two groups of studies referred to above. The question which we are facing is this: How did the conditions under which the two sets of investigations were carried on differ? In the case of Courtis' experiments the only difference in conditions appears to have been the fact that the tests for careful reading were accompanied by rather rigid tests for comprehension, while those for normal reading were not, the subjects being merely asked to read understandingly. The results for the two sets of tests show clearly that careful reading

involved the subordination of speed to meaning. All the other tests, which were discussed in connection with the second group above, were accompanied by rather rigid tests for comprehension, in consequence of which the reading might be classified as careful reading. However, at least a part of the studies classified under the first group were also accompanied by comprehension tests, especially those given by Starch. And in any event the scores obtained through the two sets of studies, especially in the case of the upper grades, do not warrant the unconditioned classification of the former with Courtis' "normal" type and the latter with his "careful" type. There must then be other conditions which differentiate the two groups of studies. At least two of these appear significant. To begin with, a special effort was made in almost every instance in connection with the second group of studies to select such reading materials as would fall unquestionably within the range of the comprehension of the several classes of subjects. In the second place, the selections were printed with uniform type and length of line. These conditions do not appear to have been as uniform in connection with the first group of tests, the pupils in many instances reading from supposedly graded readers which represented, to say the least, very varying physical conditions.

It would appear, then, that uniformity in the speed of reading is most likely to appear in cases where speed is somewhat subordinated to comprehension, where the reading materials are carefully graded so as to fall within easy range of the comprehension of the individuals to be tested, and where physical conditions are as uniform as possible. These facts, together with those available from the present investigation, do not, however, afford a final and unconditioned answer to the question whether elementary pupils, after once having passed the transition stage and after having thoroughly mastered the technique of reading, are able on an average under suitable conditions to read as rapidly as adults. They point strongly toward such a conclusion, however; and, to say the least, they show very clearly that elementary pupils are capable of reading much more rapidly silently than has formerly been supposed. Further carefully controlled experi-

mentation will of course throw much more light on this important problem.

4. *Refixations.*—The prevalence of refixations appears to be pretty definitely correlated with age, the number decreasing progressively with the increase in the age of the groups. Accordingly, the elementary group represents the largest number and the adult group the smallest. The same tendency is also more or less in evidence in the case of the subgroups. There are, however, in evidence striking exceptions. In the case of the silent reading of the elementary group, for instance, the second-grade pupils show the least number of refixations. In the case of the oral reading, on the other hand, the second- and third-grade pupils represent the largest numbers. In the high-school group the Seniors represent more refixations than the Juniors and the Sophomores more than the Freshmen. All in all, then, individual variation is strongly in evidence, even in the presence of larger general tendencies.

5. *Average deviations.*—Marked average deviations in connection with any of the factors discussed heretofore indicate the absence of well-defined habits making for uniformity. Their prevalence, as in the case of the refixations, appears to be rather closely correlated with the age of the groups, the elementary group showing the largest number and the adult group the smallest. The same general tendency is in evidence in the case of the subgroups, though there are important exceptions. A considerable degree of correlation exists between refixations and deviations, showing that the two types of irregularity are conditioned, to a certain extent at least, by common factors. These irregularities appear, further, to be pretty closely correlated with the rate of reading, the rapid readers as a class representing the smallest amount and the slow readers the largest amount of irregularity. Dearborn observed similar tendencies (19).

6. *Comprehension.*—The last two columns of Tables IV and V give the data for the comprehension tests. The averages for the high-school group are considerably lower than those for the elementary group. This is in all probability due to differences in the selections, the selection read by the former being largely descriptive,

while that read by the latter was narrative. Although the two sets of questions were seemingly nearly alike in their requirements, it was quite evident that pupils found it more difficult to answer questions based upon description than those based upon narration. Several students stated after answering the questions that it was very difficult in answering descriptive questions to distinguish between fact and fiction. It is not probable, therefore, that the differences between the two groups ought to be regarded as significant.

The correlation between reading rate and comprehension is not strong. There are in evidence, however, tendencies, some of which at least may be significant. In the case of the silent reading the rapid readers represent on an average a higher degree of comprehension than do the slow. In the case of the silent reading of the elementary group the ten most rapid readers average 83 per cent in comprehension, while the ten slowest average 77 per cent; in the case of the silent reading of the high-school group the eight most rapid readers average 72 per cent in comprehension and the eight slowest 68 per cent. While these tendencies are not particularly marked, they nevertheless point toward the conclusion that there is a positive correlation between rate and comprehension in the case of silent reading. That rapid silent readers tend to surpass the slow in comprehension has been repeatedly shown. In the case of Gray's recent investigation in Cleveland 10 per cent of the individuals show rapid speed and good quality of comprehension, while only 4 per cent show rapid speed and poor quality; on the other hand, only 4 per cent show slow speed and good quality, while 9 per cent show slow speed and poor quality (20).

In the case of the oral reading the results would seem to be reversed, though perhaps not with sufficient force to be significant. The ten most rapid oral readers of the elementary group average 84 per cent in comprehension, while the ten slowest average 87 per cent; in the case of the high-school group the eight most rapid readers average 59 per cent and the eight slowest 60 per cent. As stated above, these differences are too slight to warrant definite conclusions, but, such as they are, they at least suggest the pos-

sibility that rapid oral reading may not be compatible with a good quality of comprehension.

D. COMPARISON OF SILENT AND ORAL READING

Another important aim of the present investigation was to make a careful comparison of silent and oral reading. Accordingly, the data for silent reading are throughout paralleled with data for oral reading. Tables III, IV, and V give the complete data for the two types of reading, the arrangement being such that the comparisons can readily be made. Figs. 1 and 2 show the distributions on the basis of the number of pauses for silent and oral reading, respectively; Figs. 3 and 4 show the distributions on the basis of the duration of pauses for silent and oral reading, respectively; and Fig. 5 shows the distributions on the basis of the perception time for the two types of reading.

1. *Number of pauses.*—The averages of the groups show that oral reading requires on the whole from 1.6 to 1.8 pauses in excess of silent reading. In other words, oral reading necessitates in this respect an excess expenditure of 24–28.5 per cent. An examination of the data for the subjects composing the groups shows great individual variation. The differences in the number of pauses in the case of the two types of reading vary for the adult group all the way from 0 to 4.1, for the high-school students from −0.8 to 3.0, and for the elementary pupils from 0 to 4.1. That silent reading offers possibilities for great economy in the use of pauses is obvious, but it is quite evident that many individuals fail to realize this advantage. It should be noted, however, that large differences in the number of pauses in the case of the two types of reading do not necessarily indicate efficiency. They may be due to the use of an excessively large number of pauses in connection with oral reading. Compare in this connection, for instance, adult individuals Nos. 4, 5, and 6 with adult individuals Nos. 1, 3, and 7. Both groups show great efficiency in the use of pauses in connection with silent reading. The former show large differences between the number of pauses in silent and oral reading, while the latter show only slight differences. An examination of the data shows very clearly that the large differences in the

case of the former are due to the fact that these subjects make unusually heavy demands upon the number of pauses in connection with oral reading. On the whole, however, it will be observed that large differences between the number of pauses in silent and oral reading are rather characteristic of rapid readers.

2. *Duration of pauses.*—The advantages of silent reading are quite as much in evidence in the case of the duration of pauses as in the case of their number. The comparisons in Tables III, IV, and V show that the durations for the groups average from 62.3 to 84.7 σ higher in oral than in silent reading. In other words, there is in oral reading an excess expenditure in the duration of pauses varying from 20 to 27 per cent. For the individuals composing the groups the range of differences is of course much wider, varying in the case of the adults from -50 to 170 σ, in the case of the high-school students from -34 to 238 σ, and in the case of the elementary pupils from -52 to 208 σ. Large differences, however, as in the case of the number of pauses, are not necessarily indicative of economy in connection with fixation time. They may be due to exceptionally long duration times in connection with oral reading. Such appears to be the case, for instance, with adult individual No. 15, high-school individual No. 7, and elementary individuals Nos. 2, 10, and 12. On the whole, large differences between the number of pauses in silent and oral reading are rather characteristic of rapid readers.

It is rather difficult to account for the negative cases—the cases in which the duration of the pauses in silent reading exceeds the duration of the pauses for oral reading. These cases constitute about 10 per cent of the total. They are rather equally distributed among both fast and slow readers.

3. *Perception (or reading) time.*—The average perception time per line is the product of the average number and the average duration of the pauses. It constitutes the total reading time exclusive of the time required for the interfixation movements and the return sweep. Since the time required for these movements is very short and rather constant, the average perception time per line may be regarded as a comparatively reliable index to speed efficiency. Tables III, IV, and V show that the perception time

averages for the several groups are from 970.7 to 1,258.8 σ higher in the case of oral than in the case of silent reading. The oral reading requires on an average from 44 to 64 per cent more perception time than does the silent. Individual variations are, of course, much more marked. In the case of the adult group the differences in the perception time for the two types of reading vary from -117.0 to 2,120.8 σ; in the case of the high-school group from 36.8 to 2,316.4 σ; and in the case of the elementary group from 311.6 to 2,937.2 σ. Some individuals read practically three times as fast silently as orally. Note, for instance, adult individual No. 4, high-school individual No. 1, and elementary individuals Nos. 2 and 5. On the other extreme, one individual actually requires more time in silent than in oral reading.

On the basis of the number of words perceived or read per second the individuals included in the three groups ranged in the case of silent reading from 8.68 to 2.71 words, the average being 4.98 words; in the case of oral reading the same individuals ranged from 5.88 to 2.24 words, the average being 3.21 words. The most rapid silent reader reads thus a little more than three times as fast as the slowest, while the most rapid oral reader reads a little more than twice as fast as the slowest. These proportions are in close agreement with the results of other investigations carried on under similar conditions. Dearborn's most rapid silent readers read three times as fast as the slowest. Huey's twenty subjects averaged in normal silent reading from 2.5 to 9.8 words per second and in oral reading from 2.2 to 4.7 words per second. More extended recent investigations show very definitely that the range of individual variation in the case of silent reading is in reality even more marked than the foregoing figures might indicate. The results of tests recently given in Cleveland, Ohio, show very clearly that the range in silent reading may frequently be more than twice that of oral reading (21). When the individual scores are reduced to group averages, the ratios of such averages in the case of silent and oral reading do not appear to vary materially from the corresponding ratios in the case of the present study. The Cleveland pupils of Grades 2–8 averaged 15.1 lines per minute for oral reading and 20.7 lines per minute for silent

reading, while the 83 individuals of the present investigation averaged in the case of oral reading 3.21 words per second and in the case of silent reading 4.98 words. It is highly probable that the somewhat more limited range of individual variation, evident in connection with the silent reading of this study, is due to the experimental conditions. Moreover, the reading was distinctly of the careful type, speed being subordinated to meaning. This, as was evidenced by Courtis' results, tends to lessen the range. In any event, the advantages of silent reading as compared with oral are clearly in evidence. Fig. 5, which shows a comparison of the distributions on the basis of the perception time for the two types of reading, brings this out very forcefully. It is very probable, however, that the differences should be much more marked, especially in the case of trained adults.

4. *Refixations.*—It will be observed that refixations are practically without exception much more in evidence in the case of oral than in the case of silent reading. This is due in part to the fact that the number of fixation pauses is greater in oral than in silent reading and in part to the fact that the eye is often far in advance of the voice, and as a result is forced at times to return for purposes of orientation.

E. SUMMARY AND CONCLUSION

The fixation pause comprises, as we have seen, all but a very small fraction of the total reading time. It is the only period of significant stimulation. Whatever indirect vision may be present during rapid eye-movement, such as the return sweep and interfixation movements, serves largely purposes of orientation. Accordingly, our interest has centered first of all about the pause, its nature, number, duration, and location, as well as about total perception or reading time.

The pause involves both central and peripheral vision, the latter conditioning a significant preliminary survey, while the former serves to "correct, to confirm, and to intensify" the more or less shadowy impressions coming through the medium of peripheral vision. On the physical side the pause involves elaborate motor adjustments which condition the perceptual and assimilative processes.

In number the pauses vary for the individuals of all groups, in the case of silent reading from 4.1 to 10.8 per line (90 mm.) and in the case of oral reading from 6.1 to 11.5 per line. The corresponding average number of words perceived per pause ranges for silent reading from 2.15 to 0.93 and for the oral from 1.62 to 0.86. In the case of the groups the number of pauses is 6.5 for adults, 7.0 for high-school students, and 6.3 for the elementary pupils in silent reading, and in the oral, 8.2, 8.6, and 8.1, respectively. The corresponding figures for the number of words perceived per pause are in the case of silent reading 1.54, 1.43, and 1.59, respectively, and in the case of the oral 1.22, 1.16, and 1.23, respectively. All these figures show, of course, that the number of pauses is subject to great individual variation. Oral reading makes heavier demands upon the number of pauses than the silent, requiring an excess expenditure of from 26 to 28 per cent. The correlation between the average number of pauses per line and the total perception time per line is quite marked, showing that the number of pauses is an important factor in determining an individual's rate of reading. In spite of this it does not appear, however, that a momentary increase in the speed of reading is accompanied by a noticeable decrease in the number of pauses. To what extent a permanent increase in the rate of reading brought about by persistent practice would involve a reduction in the number of pauses is an interesting, but as yet unsolved, problem.

The durations of the pauses vary on an average in the case of all the subjects from 214 to 470 σ for silent reading and from 230 to 520 σ for oral reading. In the case of the groups the average duration of the pauses is 308.2 σ for the adults, 311.1 σ for the high-school students, and 314 σ for the elementary pupils in silent reading, and in the oral, 380.8, 372.9, and 398 σ, respectively. These durations are somewhat higher than those of previous experimenters, because the reading was in this case of the careful rather than the rapid or maximal type. A momentary increase in the speed of reading is clearly conditioned by a reduction in the duration of pauses. The same thing is undoubtedly true in the case of a permanent improvement in the rate of reading, though this has not as yet been experimentally demonstrated. While there is fairly marked correlation between the average duration

of pauses per line and the total perception time per line, a short duration of pauses does not in nearly all cases imply a rapid reader. It is quite probable, however, that the speed of reading could in the case of these exceptions be materially improved by consciously directed practice resulting in a reduction in the duration of pauses.

A study of the location of fixation pauses has shown that there is in evidence at least a tendency toward fixating apperceptive units centrally. In part this is undoubtedly due to the fact that we are in the habit of viewing most objects as units to start with. The tendency toward central location is conditioned and facilitated, on the one hand, by contributions from peripheral vision and from the context, and interfered with, on the other hand, by a variety of factors, such as defective motor control, tendencies toward the formation of short-lived motor habits, and objective peculiarities demanding analysis. Generally speaking, the words within which the pauses fall do not appear to belong prevailingly to any one class, nor to a specific group of classes. In the case of the slow readers especially such a selection would be almost a physical impossibility, since most words are fixated at least once. In the case of average and rapid readers many words are bound to escape fixation. These appear to be most frequently short words which combine readily with others to form apperceptive units, the most common of these being pronouns, prepositions, short adjectives, and auxiliary verbs. There are, however, in evidence numerous exceptions to the tendencies which have been pointed out, and when all is said and done, it must be admitted that the demands of perception appear in many cases to be met quite as adequately by fixation near either end of the apperceptive unit as by one centrally located.

The total perception time per line varies in the case of the silent reading from 1,140 to 3,684.8 σ, and in the case of the oral from 1,702 to 4,454 σ. In terms of the number of words read per second the figures range for silent reading from 8.68 to 2.71 words and for oral reading from 5.88 to 2.24 words. The perception time averages for the three groups are in the case of silent reading, 2,012.4 σ for the adults, 2,229.7 σ for the high-school students, and 1,972.7 σ for the elementary pupils. In the case

of oral reading the corresponding figures are 3,131.5 σ, 3,200.4 σ, and 3,231.5 σ, respectively. In terms of the number of words read per second the corresponding figures are in the case of silent reading, 4.9, 4.5, and 5.1 words, respectively, and in the case of the oral, 3.2, 3.12, and 3.08 words, respectively. The most rapid silent readers tend thus to read a little more than three times as fast as the slowest and the most rapid oral readers a little more than twice as fast as the slowest.

A comparison of the reading of the several groups has brought out few significant differences. The number of pauses is uniform. The duration of the pauses is nearly as uniform, though there is in evidence a tendency for the children to represent slightly longer duration times, in all probability because the processes of adjustment involved in fixation may not have been as thoroughly perfected in the case of children as in the case of adults. The perception time or reading rate is also practically the same for the three groups. Other studies involving careful reading show similar results in this respect. The facts in the case point strongly toward the conclusion that the rate of reading tends to be rather uniform in the case of individuals after they have once passed the critical transition stage and have mastered the mechanics of reading, provided that speed be somewhat subordinated to meaning or comprehension, that the reading materials be carefully graded so as to fall within easy range of the comprehension of the individuals to be tested, and that physical conditions be as uniform as possible. The most marked difference between the groups is in evidence in the case of the irregularities, refixations being much more common, and average deviations being often materially larger in the case of children than in the case of adults.

A comparison of the individuals comprising the several groups shows, on the other hand, that there is almost no limit to individual variation. Other recent studies, especially those concerned with the rate of reading and with comprehension, show similar tendencies. While both of these factors, reading rate and comprehension, appear to be somewhat correlated with scholarship as shown by student grades, there is, as we have seen, practically no correlation between reading rate and age and grade rank, at least beyond a

certain point. A second-grade pupil may actually read more rapidly than an eighth-grade pupil, a high-school student, or an adult of considerable accomplishment. In fact, such cases are quite common. This whole situation shows very clearly that reading ability is quite as much a variable factor as are mathematical, language, and other abilities. The reading rate of slow readers—and all others, of course—may no doubt be materially improved by persistent training and practice. To what extent this is possible and desirable will have to be determined experimentally. In fact, standards are very rapidly being developed even now. One thing is very certain, and that is that it will be quite futile to attempt to reduce all to the same level; individual ability will have to be respected here as much as elsewhere.

The differences between the results of silent and oral reading are not as marked as might be expected. On an average the subjects of the present experiment read 57 per cent more material silently than they did orally in a given time. Individual variation is, however, much more marked, some individuals reading three times as fast silently as orally, and one actually requiring more time for silent than for oral reading. Other studies show even less marked differences. The Cleveland pupils read 37 per cent more silently than orally, and Oberholtzer's study shows an excess of approximately 30 per cent. These differences are, however, more significant than might appear at first sight. They show that the rate of silent reading is materially higher than that of oral reading, even under ordinary conditions, when no special effort is made to distinguish between the two, and in the case of individuals who have been trained almost exclusively in oral reading. The very marked differences which are in evidence in the case of some individuals indicate very clearly that it is possible to make much greater distinctions between the two types of reading than are ordinarily made. The rate of oral reading, although subject to considerable variation, is confined within relatively narrow limits because of its dependence upon the physiological mechanism involved in vocalization. Silent reading, on the other hand, is much more independent of physiological factors, though by no means entirely so, since the great majority of readers are dependent

upon the so-called inner speech of reading. This involves, of course, auditory and motor elements, the one predominating in some cases and the other in others. This inner speech is subject to very varying degrees of abbreviation, the degree being largely determined by a subject's dominant mode of imaging. In the case of the visual type the inner speech is reduced to a minimum, though it is probably rarely entirely absent. Individuals of this type are by nature rapid readers, other conditions being equal. Their speed is not due to scanning, however, for they have no occasion to resort to this, since there is almost no limit to the rate of visualization. The motor type, on the other hand, tends to represent the slowest readers, the dependence upon the physiological mechanism being in this case quite marked. The auditory type ranges between the two, the hearing of the words being in this case often quite vestigial. This type appears to be much more common than either of the other two types. Most of the evidence which the writer has been able to gather through interviews with a large number of individuals seems to support the conclusion that the auditory-motor type of reader can compete with the visual only when he is able to resort to scanning. There can be little doubt that rapid readers fall almost exclusively into these two classes—those, on the one hand, who are good visualizers, and those, on the other hand, who have acquired the ability to gather meaning from the printed page without definitely reading all words and sentences. This does not imply, of course, that the rate of reading may not be improved somewhat by lessening the number of pauses, and especially by reducing their duration; but such improvement is severely limited when compared with the results of scanning. It is quite possible, too, that if the training in oral reading were discontinued at an early stage and training in rapid silent reading were stressed, the tendencies toward inner speech might be greatly reduced and visualization cultivated, at least in part. As a matter of fact, we appear to have the ability to take in all kinds of situations visually without speech accompaniments. This is true even in the case of the interpretation of many printed symbols. The problem is one which will have to be worked out experimentally. In any event, whether improvement

in the rate of reading is to come chiefly by resorting to scanning, or whether it is to come through training in visualization, it is very evident that the teaching of reading demands expert knowledge and skill in place of the present haphazard and empirical type of procedure.

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PLATE I

1 2 3 4 5 6 7 8 9 10 11 12 13

CHAPTER V

THE MOTOR BEHAVIOR OF THE EYE IN READING

A. MOVEMENT IN THE HORIZONTAL PLANE

1. *Description of records and plates.*—As previously indicated, the film running in the vertical plane recorded head- and eye-movement in the horizontal plane. The records for movement in this plane represent for each fixation pause a nearly vertical line of dots and spaces; for each interfixation movement a line consisting of one or two slightly extended dots and spaces running somewhat diagonally to the right; for each refixation movement a similar line running to the left; for the return sweep a much longer but also slightly diagonal line running to the left, the line consisting in this case of more extended dots and spaces, the number varying all the way from one dot and two spaces or two dots and one space to two dots and three spaces; for head- and eye-movements a variety of deviations and irregularities affecting both directions. Movements in the vertical plane are indicated on these records in a general way by an alternate spreading and crowding of the dots. Since the printing of the films does not correct the perversion caused by the motion of the films, an upward movement is roughly indicated by a crowding and shortening of the dots and a downward movement by a spreading and lengthening of the dots. Some of the crowding and spreading may, however, be due to slight changes in the running speed of the films. The varying widths of the records for movement in the horizontal plane are due largely to the fact that the distances between the eyes and the film varied with different individuals.

Plates I–IV inclusive represent a variety of records for movement in the horizontal plane. The first record of Plate I is a record of light reflected from a polished bead fastened to the apparatus; it is intended to detect possible vibrations of the apparatus in the horizontal plane. The second and fourth records are records for head-movement in the horizontal plane, the former

for silent and the latter for oral reading; they are records of light reflected from a polished bead fastened to a pair of spectacle rims worn by the reader. The third and fifth records are the corresponding records for head- and eye-movement combined. A comparison of these two types of records makes possible the isolation and characterization of eye-movement alone. The remaining eight records make possible a comparison of silent reading at maximal and at normal rates, the records of four rapid readers being represented; records 6, 8, 10, and 12 represent the maximal and records 7, 9, 11, and 13 the normal rate.

Plate II shows typical records from the reading of children for both silent and oral reading, the second and third grades being represented by two individuals each and grades 4–7 inclusive by one individual each. Accordingly, records 1 and 3 represent the silent and records 2 and 4 the oral reading of second-grade pupils—elementary individuals Nos. 2 and 12; records 5 and 7 represent the silent and records 6 and 8 the oral reading of third-grade pupils—elementary individuals Nos. 20 and 21; record 9 the silent and record 10 the oral reading of a fourth-grade pupil —elementary individual No. 7; record 11 the silent and record 12 the oral reading of a fifth-grade pupil—elementary individual No. 8; record 13 the silent and record 14 the oral reading of a sixth-grade pupil—elementary individual No. 4; and record 15 the silent and record 16 the oral reading of a seventh-grade pupil —elementary individual No. 15.

Plate III is intended to illustrate binocular behavior and adjustment in connection with reading, the records for both eyes being shown in each case. The first pair of records represents the rapid silent reading of an easy selection by adult individual No. 12; the second the normal silent reading of adult individual No. 27; the third the silent reading of elementary individual No. 2; the fourth the silent reading of elementary individual No. 20; the fifth the silent reading of high-school individual No. 8; and the sixth the oral reading of elementary individual No. 3.

The several pairs of records of Plate IV serve to illustrate additional features of binocular behavior and adjustment. The first pair represents a series of normal fixations on the part of an adult

reader, the points fixated being located at the edges of the printed page; the second represents the silent reading of high-school individual No. 9, the point of interest being especially the series of fixations near the middle of the records; the third represents the silent reading of adult individual No. 16, the point of interest being within the series of fixations near the middle of the records; the fourth and fifth pair represent the oral reading of elementary individuals Nos. 4 and 20, respectively, the points of interest being in each case connected with the last return sweep.

2. *Head- and eye-movement in the horizontal plane.*—A careful examination of the first record of Plate I shows that vibrations of the apparatus in the horizontal plane were practically non-existent. An examination of records 2 and 4, the records for head-movement alone, on the other hand, indicates very clearly that head-movement is a factor to be reckoned with. A comparison of these records with records 3 and 5, the ordinary eye-movement records, shows that most of the irregularities which stand for head-movement in the case of the former are also present in the case of the latter, indicating, of course, that ordinary eye-movement records tend to represent a complication of head- and eye-movement. Accordingly, it becomes our task to analyze the records and to distinguish between these two types of movement.

An examination of records 2 and 4, the records for head-movement alone, reveals several types of disturbances. The most prominent is that indicated by the wavelike deviations which may be observed at points designated by *a*. At first sight these deviations might be regarded as indicative of vibrations of the apparatus; however, record 1, taken immediately before to test the apparatus in this respect, gives no indication whatever of such vibration. It is barely possible, on the other hand, that the subjects may have disturbed the apparatus sufficiently to set up the vibrations in question; this is not probable, however, since the apparatus rested on a heavy table which was seemingly well secured. Moreover, a bodily movement of sufficient impetus to initiate such disturbances of the apparatus could scarcely take place without noticeable head-movement, but the records give no indication of

such head disturbance immediately preceding the wavelike deviations. Furthermore, the deviations are far from uniform in wavelength and amplitude. Not only do those of record 4 differ from those of record 2, but there are differences in evidence in the case of any one record. The facts in the case appear thus to point toward the more probable hypothesis that the deviations are indicative of slight oscillations of the head in the horizontal plane, the eyes being in such cases compelled to move with the head, as will be shown later. Such oscillations of the head are very easily set up even in cases where a seemingly firm headrest is used. Such disturbances would also show somewhat less regularity than vibrations of the apparatus. They would naturally, because of the irregularities caused by articulation, show less regularity in the case of oral than in the case of silent reading. A comparison of the two records indicates that such is actually the case. While this kind of disturbance is found at some point or other on the records of practically all readers, it tends to occur persistently on the records of only about 10 per cent of the subjects. In the last analysis, whatever the cause of the disturbance may be its real significance lies in the fact that it appears equally on the records for head-movement and for head- and eye-movement combined, and so might easily be mistaken for eye-movement. We shall designate this type of irregularity tentatively as "head-movement of the first type."

A second kind of disturbance is indicated on the records by well-marked deviations toward the left; these occur particularly in connection with oral reading. Note the most striking instances on record 4 at points designated by *b*. A comparison of these points with approximately identical points of record 5 shows that these deviations are closely related to interfixation movements. Just what this relationship may be is not certain. At times these movements appear to occur a moment before, at times simultaneously with, and at times a moment after, the interfixation movements of the eye. When the movements occur immediately before or immediately after the interfixation movements, the eyes, at least in part, are carried along with the head. We shall speak of such movement as "head-movement of the second type."

PLATE II

A third type of irregularity is indicated on the records by a gradual change in direction. It appears to imply a slow and probably quite unconscious shifting of the head. It is limited almost exclusively to oral reading and appears to be closely related to the more pronounced head-movement of the second type. The duration and form of this shifting movement vary materially; at times the shifting affects several successive pauses, and at other times it appears to be coextensive with individual pauses. The form of the movement is such as to give the records of the pauses over which it extends a curved effect, the curve extending in some instances to the left and in others to the right. Note record 4 of Plate I and records 2, 4, 6, 8, 10, 12, 14, and 16 of Plate II at points marked *c*. The eyes appear to be carried along with the head except in cases where they have occasion to move independently, as during connecting movements or binocular adjustment. This type of disturbance will be spoken of as "head-movement of the third type."

A fourth type of disturbance appears in the form of a general irregularity which causes the records to appear shaky and unsteady. When these irregularities are examined under an enlarging glass, they are found to consist of comparatively irregular deviations, differing from those involved in head-movement of the first type by the absence of regularity in wave-form and amplitude, and by the fact that they are less marked as far as size is concerned. They are particularly common in connection with oral reading, being in this case, in part at least, indicative of disturbances set up by articulation. In so far, however, as they are found in connection with both silent and oral reading, they must be, in part at least, also indicative of disturbances set up by such functional activities as respiration and pulsation. Observe, in connection with oral reading, record 4 of Plate I at points designated by *d*, and in connection with silent reading, particularly records 6–9 of Plate I at points indicated by *d*. As in most previous cases, the eye appears to be carried along with the head during such movement. These irregularities will be referred to as "head-movement of the fourth type."

Having characterized the leading types of head-movement, we are prepared to consider eye-movement as such. Several

types are in evidence. The first and most striking type appears on the records in the form of a gradual change in the direction of the records of fixation pauses, the record of the right eye tending toward the left and that of the left eye toward the right. It appears to involve a slow and continuous shifting of the eye during fixation. It is most evident in connection with the initial fixation pauses of each line, but is by no means absent in the case of subsequent pauses, as will be pointed out later. It takes place quite independently of head-movement. A comparison of records 2 and 3 of Plate I at points representing the initial fixation pauses brings this out quite clearly. It is somewhat more difficult to single out this type of eye-movement on the records for oral reading because of the presence of head-movement of the third type. This type of eye-movement, as will appear later, represents convergent adjustment in connection with fixation. It is designated by 1.

A second type of eye-movement appears on the records in the form of a rather sharp deviation at the initial points of the records of certain fixation pauses, the deviations implying in this case a movement of both eyes in a direction opposite to that of the preceding return sweep or interfixation movement. Observe in this respect particularly records 1 and 2 of Plate III at points designated by 2. As will be pointed out later, this type of movement appears to be indicative of a natural tendency for both eyes to move in the same lateral direction before responding to the more complicated and difficult process of convergent adjustment.

A third type of eye-movement appears on the records in the form of isolated deviations. There is rarely more than one of these in evidence in connection with any one fixation pause. The prevalence of this type of eye-movement varies greatly with individuals; in the case of some it is very common, especially in connection with silent reading; and in the case of others it is almost entirely absent. Records 6–9 of Plate I represent an unusual amount of such disturbance; note particularly the points designated by 3. Records 10 and 11 of Plate I and records 1–4 and 9 and 10 of Plate III are typical of the opposite extreme. There is no indication whatever that such movement is in any way

purposive. It is in all probability due to a lack of balance on the part of the muscles of the eyes.

It is not probable that eye-movement in connection with fixation is limited to the three types described above. There are indications, for instance, of an unsteadiness of the eye resembling closely head-movement of the fourth type, but since the eye is carried with the head in the case of the latter causing the disturbance to be recorded on the records for head- and eye-movement combined, it is very difficult to distinguish between the two. The extent of the present study at least does not warrant a final distinction. There must also be a certain amount of compensatory eye-movement in connection with certain types of head-movement, but it has not been possible with the present technique to point this out definitely.

A rapid survey of the records of the several plates will serve to bring out further the nature and the prevalence of the different types of head- and of eye-movement. Records 6–13 of Plate I represent silent reading. The sixth, seventh, eighth, and ninth show an exceptional amount of unsteadiness. Most of this is head-movement of the fourth type and eye-movement of the third type; note the most striking instances of the former at points designated by *d* and those of the latter at points designated by 3. Eye-movement of the first type is also present; observe in this respect the pauses indicated by 1. Records 10 and 11 represent unusual steadiness, the disturbances being practically limited to head-movement of the fourth type and eye-movement of the first type; observe the former at points indicated by *d* and the latter at pauses marked 1. Records 12 and 13 show an unusual amount of head-movement of the first type; note the deviations in the proximity of points designated by *a*. Eye-movement of the first and second types is also clearly in evidence at points marked 1 and 2, respectively.

Plate II represents, as previously indicated, the reading of children—records 1, 3, 5, 7, 9, 11, 13, and 15 representing the silent and records 2, 4, 6, 8, 10, 12, 14, and 16 the oral. In the case of silent reading head-movement is practically confined to the fourth type; observe the most striking instances at points

designated by *d*. This type appears even more prominently on the records for oral reading, the deviations being more marked. At times it is difficult on both kinds of records to distinguish between this and eye-movement of the third type. In the case of the oral records head-movement of the third type is also strongly in evidence. Note the most marked instances at points designated by *c*. Eye-movement of the first type is much in evidence, particularly in the case of the records for silent reading. Observe the most striking instances at the pauses indicated by 1. The second and third types may also be observed at points marked 2 and 3, respectively.

Although Plate III is intended chiefly to illustrate binocular motor behavior, the several pairs of records may serve to illustrate further the several types of head- and eye-movement. All but the last pair represent silent reading. The first pair presents several interesting features. Head-movement is almost entirely absent, only the fourth type being slightly in evidence. Eye-movement, on the other hand, is well represented, particularly the first and second types; note points designated by 1 and 2, respectively. The second pair represents the extreme as far as steadiness is concerned; head-movement is limited to some very slight instances of the fourth type, and only minimal degrees of eye-movement of the first type are in evidence. It is interesting to note, however, that this individual rarely succeeds in making a continuous return sweep, two movements separated by an interval of approximately 160 σ being almost invariably required. The fourth pair, one record of which has been previously referred to, represents a rather marked amount of head-movement of the first and fourth types; note the points at *a* and *d*, respectively. Eye-movement of the first type is also in evidence. The fourth pair gives slight indications of head-movement of the first type and also of the fourth. Each of the three types of eye-movement is somewhat represented. Note particularly the striking instances of eye-movement of the first type at points designated by 1. The fifth pair represents considerable steadiness; note, however, the indications of head-movement of the fourth type, and also those of eye-movement of the first type. The fifth pair represents

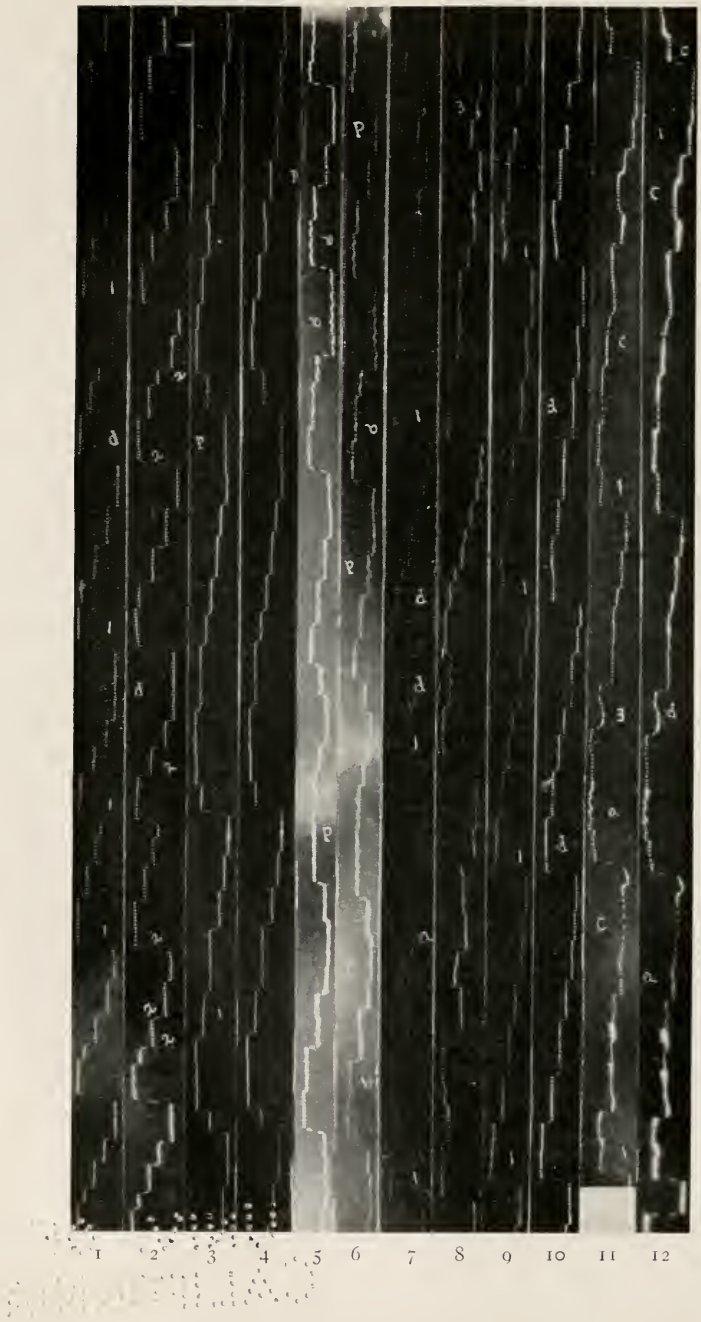
head-movement of the first, third, and fourth types and eye-movement of the first and third types. The alternate spreading and crowding of the dots are indicative of head- and eye-movement in the vertical plane, this being very common in connection with oral reading.

3. *Comparison of records for silent reading at maximal rate with records for silent reading at normal rate.*—Records 6–13 of Plate I make possible a comparison of silent reading at maximal and at normal rates. Near the close of the present investigation a number of rapid readers were asked to read two easy passages, one at normal and the other at maximal rate. The results of four of these individuals are shown on Plate I, records 6, 8, 10, and 12 representing reading at maximal rate and records 7, 9, 11, and 13 reading at normal rate. On an average these subjects read approximately four lines at maximal speed for every three lines at normal speed. The difference between the average number of pauses per line is almost negligible for the two types of records, those for reading at normal rate averaging slightly higher. The chief difference lies in the duration of pauses, these being materially longer in the case of reading at normal rate. Compare the several sets of records in this respect. Beyond this the two types of records present no marked differences. It is interesting to note, however, that some individuals make a greater distinction between maximal and normal reading than others. Compare, for instance, records 6 and 7 with records 10 and 11. In general, we may conclude, however, that a momentary silent reading at maximal rather than at normal rate involves a shortening of the duration of the pauses rather than a lessening of their number. But this leaves unsolved the problem as to what would happen if the subjects were to engage in practice extending over a considerable period of time, gradually forming habits of reading at maximal rate. It is quite possible that improvement brought about in this manner would involve a reduction of the number as well as the duration of pauses.

4. *Comparison of the records of children with those of adults.*—As previously indicated, all the records of Plate II, records 5, 6, 7, 8, 11, and 12 of Plate III, and records 12 and 13 of Plate I

represent the silent reading of children; records 9 and 10 of Plate III represent the reading of a third-year high-school student; the remaining records represent the reading of adults. In making comparisons it must be remembered that records 6, 8, and 10 of Plate I and records 1 and 2 of Plate III represent adult silent reading of easy selections at maximal rate and so are not as strictly comparable with the normal reading records of the children as are the rest of the adult records. It will be recalled that there was practically no difference between the results for the children and the results for the adults as far as the average number of pauses per line and the average duration of pauses are concerned, the children showing a slightly smaller number of pauses and a little longer duration of time. There was, however, a much more marked difference in connection with irregularities, especially in the case of refixations and average deviations, these being much more in evidence in the case of children. A comparison of the records above referred to serves to emphasize this fact. The records of the children show very evidently less regularity in the number and duration of pauses and in the amount of time required for the reading of successive lines, refixations occurring also more frequently. Irregularities during fixation appear also at first sight to be much more common in the case of children than in the case of adults. A careful comparison of a large number of records shows, however, that these differences are more apparent than real. The fixation records of children represent on the whole remarkable steadiness and precision. Marked control is in evidence even as far down as the second grade. Observe particularly the records of the latter and also of the third grade, the pupils being seven and eight years old, respectively. These show beyond question a greater steadiness than many of the adult records, especially in the case of silent reading. Compare them in this respect with records 6–9 of Plate I. The same thing is essentially true of binocular behavior and adjustment, these being remarkably developed in the case of even the youngest readers. Compare the records of Plate III in this respect. All in all, then, the motor behavior of the eyes in reading differs in the case of children from that of adults, not so much in number and duration of pauses,

PLATE III



nor in steadiness and precision of fixation, but rather in frequency of refixation and in the regularities affecting the number and the duration of pauses, refixations and average deviations being more in evidence in the case of the elementary and even the high-school group than in the case of adults. All of this goes to show, of course, that children develop at an early age a high degree of motor control, but that their habits are as yet largely unformed.

5. *The return sweep and interfixation movements.*—While the method of time measurement employed in the present investigation is much better suited to estimate the duration of fixation pauses than the speed of the connecting movements, it affords, nevertheless, a very reliable index to the speed of the return sweep and the interfixation movements. On the records a dot and a space represent one-fiftieth of a second. On this basis it is possible to estimate with reasonable accuracy the duration of the movements in question. An examination of the records shows that the time required for the return sweep is subject to considerable individual variation, being in some cases as low as 3 seconds and in others as high as 0.05 second. A return sweep varying in duration from 0.03 to 0.04 second is very common. Note in this respect particularly records 8, 9, 10, and 11 of Plate I, records 13 and 14 of Plate II, records 1, 2, 9, 10, 11, and 12 of Plate III, and records 1 and 2 of Plate IV. Durations ranging from 0.04 to 0.05 second occur less frequently. Note, however, records 3, 4, 5, and 6 of Plate II and records 7 and 8 of Plate III. Long durations are somewhat more characteristic of children than of adults. Moreover, the time required for the return sweep is not absolutely constant in the case of any one individual, variation from line to line being by no means uncommon, though it is not as marked as might appear at first sight. In certain cases the return sweep is interrupted rather than continuous, the return sweep proper being preceded by a backward movement resembling a refixation. This is characteristic of only a few individuals, but where it does occur it tends to persist line after line, particularly in the case of silent reading. Observe in this respect records 1 and 2 of Plate II and records 3 and 4 of Plate III.

The duration of interfixation movements is also subject to considerable individual variation. The same thing is true of the durations in the case of any one individual, some interfixation movements being at least twice as long as others. On the whole, the duration of these movements varies from 0.01 to 0.03 second, durations ranging between 0.02 and 0.025 second being most common. Records 6 and 7 of Plate I represent interfixation movements of maximal duration. Note especially the instances at *x*, *y*, and *z*. Records 10 and 11 of the same plate represent interfixation movements requiring minimal durations. Note the instances at *x'*, *y'*, and *z'*. In part at least these differences in duration are due to differences in the extent of forward movement, the extent of some of these connecting movements being three and four times as great as that of others. Compare, for instance, the first and last interfixation movements of line 1 of records 10 and 11, Plate III, and also interfixation movement one of line 5 of records 1 and 2, Plate III, with the rest of the interfixation movements of that line. In some instances, however, long durations cannot be accounted for on the basis of the extent of forward movement. In such cases the movements appear to be executed very slowly. These cases are comparatively rare. They are found occasionally in connection with almost any individual. In such cases the extent of forward movement is usually quite short, the long duration being simply indicative of a gradual shifting from one fixation point to another. In a few instances, however, these slow interfixation movements tend to recur rather persistently in connection with certain individuals. Note, for instance, record 7 of Plate I. It is interesting to note that the duration of the return sweep is also long in such cases. Both phenomena imply habits of slow movement on the part of such individuals.

6. *Binocular behavior and adjustment.*—As previously indicated, the records of Plates III and IV serve chiefly to illustrate certain aspects of binocular behavior and adjustment. The records of Plate III are typical of binocular behavior as found in connection with regular reading; the first two pairs of Plate IV serve to illustrate binocular behavior in connection with a series of successive fixations of end points, while the remaining records represent

other aspects which are of interest in connection with binocular behavior and adjustment.

A rapid survey of the records of Plate III shows at a glance that there is on the whole a remarkable correspondence in the behavior of the two eyes. A closer examination, however, brings out the fact that there are at times material differences. To begin with, the two eyes rarely cover the same distance during the return sweep and during interfixation movements. The leading eye (in space) invariably covers a greater distance than the eye which follows, no matter in which direction the movement may be. The nature of the adjustment during succeeding fixation pauses shows that the leading eye covers more and the eye which follows covers less than the normal distance. In other words, the leading eye gradually retraces its excess distance during the subsequent fixation pause, while the other makes up for its deficiency by continuing very gradually in the same direction. As a result the parallel records of such pauses show a tendency to incline toward each other, the distance separating them being greatest at the beginning and least toward the end. This characteristic is naturally most in evidence in the case of the initial fixation pause of each line, this being preceded by the long return sweep during which the difference in the distances covered by the two eyes reaches its maximum. In the case of the other pauses the adjustment varies correspondingly with the extent of the connecting movements, being in many cases too slight to be evident.

On the whole, the foregoing phenomena point strongly to the conclusion that rapid movements of the eyes, such as are involved in the return sweep and the interfixation movements, are accompanied by a divergent adjustment, and that this is followed by convergent adjustment during subsequent fixation pauses. As far as the horizontal plane is concerned, the eyes move outward during divergence—the two eyes moving, of course, in opposite directions; during convergence the directions are reversed, the eyes moving in this case inward (1). Divergence accounts at once for the difference in the distances traversed by the two eyes in the case of the connecting movements. The leading eye gains because it moves in the same direction in which the divergent

adjustment is leading it; the eye which follows falls behind because it moves in a direction opposite to that in which the divergent adjustment is leading it. Convergence, on the other hand, accounts for the character of the subsequent adjustment. The fact that the eyes move inward in this case enables the leading eye to retrace its excess distance, and similarly it allows the eye which follows to make up for its deficiency. As a matter of fact, this adjustment, both divergent and convergent, is comparatively slight after the initial fixation pause, so slight that it is at times scarcely perceptible. There are, moreover, marked individual differences. There is no reason to believe, however, that these forms of adjustment are ever entirely absent. A critical examination of more than two hundred records shows no exceptions, at least as far as divergence is concerned. This, it must be remembered, is somewhat more easily detected on the records than convergence, simply because its effects are confined to the comparatively short and undisturbed records of the connecting movements, while those of convergence appear on the records of fixation pauses, these being comparatively long and subject to a variety of other disturbances.

It is quite evident by this time that convergent adjustment is responsible for eye-movement of the first type. In the case of oral reading this is frequently somewhat complicated with head-movement of the third type. Eye-movement of the second type also finds its explanation in this connection. It will be remembered that this involves at the beginning of a fixation a rapid lateral movement of both eyes in a direction opposite to that of the preceding connective movement. This tendency toward sympathetic lateral movement is clearly opposed to convergent adjustment; in fact, it represents, as Dr. Judd points out, a more elementary tendency and a simpler type of eye behavior than do the elaborate processes of divergence and convergence, and perception must involve processes which overcome these elementary types of movement and lead to successful convergent adjustment (2).

A rapid survey of the several pairs of normal binocular reading records will bring out more clearly the leading characteristics of binocular behavior and adjustment. The first pair of records

PLATE IV

(Plate III) represents the rather rapid silent reading of adult individual No. 12. Note first of all the very obvious difference in the distances traversed by the two eyes, both in the case of the return sweep and in the case of the interfixation movements. Observe, further, the incline character of the records of the pauses, particularly those at points designated by 1. Note also at points indicated by 2 the tendency of the two eyes to move sympathetically in the same lateral direction at the beginning of certain fixations. The second pair of records represents the normal silent reading of adult individual No. 27. It represents an extremely precise type of binocular adjustment. Divergence and convergence are in evidence in minimal degrees. An interesting characteristic of the binocular behavior of this individual appears in the fact that the return sweep is not continuous, at least two movements being invariably required. The third pair, which represents the silent reading of elementary individual No. 2, shows a similar tendency, particularly in connection with the fourth and fifth return sweeps. Divergent and convergent adjustments are in evidence, particularly at points designated by 1. Note incidentally the surprisingly precise character of the binocular behavior of an individual only seven years of age. The fourth pair represents the silent reading of elementary individual No. 20. Convergent adjustment is strongly in evidence in this case, particularly at the points indicated by 1. The binocular behavior shows again a great deal of regularity and precision, especially when it is remembered that this individual was only eight years old. The fifth pair represents the silent reading of high-school individual No. 8. Note again the difference in distances traversed by the two eyes and the subsequent convergent adjustments, particularly in connection with the initial pauses. It is interesting to note the rather vacillating and uncertain character of the adjustment in the case of the initial pauses, and to contrast this with the precise character of the adjustment in the case of subsequent pauses. The long preceding return sweep appears to interfere with muscular balance, so much so, in fact, that the subsequent adjustment is rendered rather long and difficult. The sixth pair represents the oral reading of elementary individual

No. 3. Indications of divergent and convergent adjustment are in evidence, though the latter are somewhat interfered with because of the presence of head-movement.

The first pair of records of Plate IV represents the successive fixations of two points located at the edges of a printed page. The records show accordingly a series of records of fixation pauses connected by return sweeps for both directions. Note the striking precision which characterizes the binocular behavior and adjustment. The differences in the distances traversed by the two eyes are evident only in a minimal degree, as are also the subsequent adjustments. There is in evidence throughout a slight tendency for both eyes to move at the beginning of a fixation pause in a direction opposite to that of the preceding connective movement. The reading records of this individual are not represented on the plates, but they show similar characteristics. The second pair of records represents a series of similar fixations in connection with silent reading, the reader fixating successively two marginal points when passing from one paragraph to another. It should be remembered in this connection that the difference in the width of the records of the several pairs is due to the fact that the distances between the eyes and the films varied somewhat with the different cases. The second pair shows much less precision in binocular behavior than the first. Note incidentally the differences in the distances traversed by the two eyes as well as the marked subsequent convergent adjustment. The third pair represents similar fixations in connection with rapid silent reading. The points to be fixated were located marginally between the two paragraphs, as above, except that the reader was to re-read at the conclusion of the fixations the previous paragraph rather than the one which followed. Accordingly, the point of interest centers at the stage at which the eye left the fixation point at the lower right-hand side of the paragraph and returned to the beginning of the first line of the paragraph. This necessitated a diagonal upward movement toward the left. This upward return sweep is represented on the records in part by the lines x–y and x'–y' and in part by the lines a–b and a'–b'. The diagonal upward movement of the eyes, as represented by x–y and x'–y', was very

clearly accompanied by strong divergence. Note the effect of the difference in the distances covered by the two eyes. Observe carefully, in addition, the character of the subsequent convergent adjustment at *y–a* and *y′–a′*. The incline character of the records of the fixation pauses is very much in evidence. At *b–a* and *b′–a′* the return sweep is finally completed. This instance lends strong support to our principle of explanation, illustrating, as it does, in a unique manner the nature of binocular behavior in connection with rapid eye-movements and in connection with subsequent fixation pauses. The facts, as far as they go, are in close agreement with those which Dr. Judd found in connection with his elaborate and detailed investigations of divergence and convergence (3).

The fourth and fifth pairs of records (Plate IV) represent the oral reading of elementary individuals Nos. 4 and 20, respectively. Both represent, in addition to the usual binocular characteristics, certain interesting features due chiefly to complications of head- and eye-movement. In the case of the fourth pair the adjustments at *a*, *b*, and *c* might appear to imply at first sight a rather radically different type of behavior on the part of the two eyes in connection with certain fixations. Upon closer examination, however, these differences appear to be due to a slight twisting or turning of the head, the axis of rotation being nearer one eye than the other, in consequence of which the path of the latter is more extended and different in form from that of the former. Note the apparent difference in distances covered by the two eyes at *a* and *b* and at *y–z* and *y′–z′*; note also the differences in the form of the paths, particularly in the case of the first and last instances. Eye-movement undoubtedly serves to complicate the situation, particularly at such places as *x–y* and *x′–y′*. This sweep was executed partly by the head and partly by the eyes; in addition, there are very definite indications of divergence in connection with the sweep, the latter necessitating in turn convergent adjustment. Somewhat similar characteristics are in evidence in the case of the fifth pair of records. Compare the records particularly at points between *a* and *b*. Note also the form of the return sweep at *a*. While the difference in the distances traversed by the two

eyes is due to divergence, the difference in form is due largely to a slight twisting of the head, such as was referred to above. This constitutes really a fifth type of head-movement. It occurs very rarely, however, and then almost exclusively in connection with children.

B. MOVEMENT IN THE VERTICAL PLANE

As previously indicated, the film-holder was modified in the course of the present investigation so as to make possible the measurement of head- and eye-movement in the vertical plane. The technique of the apparatus, however, did not permit the simultaneous registration of the movements of both eyes in the two planes, the movements of one being recorded for the horizontal plane and the movements of the other for the vertical plane. If the behavior of the two eyes were absolutely uniform, the results thus obtained would, of course, represent the movements of either eye in both planes. Since the behavior of the two eyes varies more or less, the results can only approximate the movements of any one eye in the two planes. However, this need not materially affect the validity of the results of our study of eye-movement in the vertical plane; the difference in the behavior of the two eyes is in the last analysis trivial.

Unfortunately no means could be devised whereby the precise location of the path of the fixation point could be located within the line. In other words, there was no way of determining whether the fixation point moved through the line near the base of the words, near the middle, or near the top. It is, of course, a well-known fact that the upper parts of words are more characteristic and consequently more crucial in perception than the lower parts. While this fact tends to support the hypothesis that the fixation point moves nearer the top than the bottom of the printed line, it does not make possible quantitative estimation. As a result, movement in the vertical plane must be discussed with reference to the eye rather than the line.

1. *Description of records and plates.*—Plates V and VI show typical records from a rather large number of records. In the case of Plate V the records for the two planes parallel each other. Two individuals and both types of reading are represented. The

first and the fifth records represent movement in the horizontal plane in the case of silent reading and the third and seventh in the case of oral reading; the second and sixth represent movement in the vertical plane in the case of silent reading and the fourth and eighth in the case of oral reading. Since the records of this plate represent head- and eye-movement combined, and are not paralleled by records for head-movement alone, the comparisons must be made on the basis of combined head- and eye-movement rather than on the basis of either head- or eye-movement.

In the case of Plate VI the records for head-movement and for combined head- and eye-movement parallel each other, the former being records for movement in the vertical plane, the light being reflected from a polished bead fastened to a pair of spectacle rims worn by the reader, and the latter being the usual corneal reflection records for movement in the vertical plane. The first record is a record of light reflected from a polished bead fastened to the apparatus. It is intended to detect possible vibrations of the apparatus in the vertical plane. In the remaining records two individuals and both types of reading are represented. The second and sixth records are records of head-movement in silent reading, the former representing rather a maximal and the latter a minimal amount of head-movement for silent reading; the third and seventh records are records of head- and eye-movement combined in connection with silent reading, the former being rather typical of a minimal and the latter of a maximal amount of eye-movement in silent reading; the fourth and eighth records are records of head-movement for oral reading, the former being rather typical of a maximal and the latter of a minimal amount of such movement; the fifth and ninth records are records of head- and eye-movement combined in oral reading, both representing an average amount of eye-movement for oral reading. The records of this plate should be read from left to right.

The reader is already familiar with the records for head- and eye-movement in the horizontal plane. Those for movement in the vertical plane may be readily understood, although they are somewhat more complicated. The pauses are in this case represented by short series of dots and spaces and the inter-

fixation movements by longer spaces between the series of dots and spaces which represent the pauses. The return sweep (from right to left) consists of one or two extended dots and of two or three spaces, the number in each case depending upon the speed of the movement; it extends toward the left from the end of the record of the last pause of the previous line to the beginning of the record of the first pause of the succeeding line. This means, of course, that the records for the last pause of the previous line and for the first pause of the succeeding line parallel each other, the record for the return sweep running between the two. These three records are naturally in close proximity, so much so, in fact, that they tend to blur when printed. On the films, however, they may be readily distinguished. The record for the reading of a given line consists accordingly: (*a*) of several of the series of dots and spaces, the number being equivalent to the number of pauses required for the reading of the line in question, the first and last excepted, since the former parallels the records for the return sweep and for the last pause of the previous line and the latter the records for the return sweep for the line in question and for the first pause of the succeeding line; (*b*) of the longer spaces between these series of dots and spaces representing the interfixation movements; and (*c*) of the complexes at the beginning and at the end of the line representing the records of the last pause of the previous line, of the return sweep, and of the first pause of the succeeding line. The records for the reading of several lines will naturally represent a series of repetitions of the foregoing. With this in mind the reader will have no difficulty in interpreting the records for head- and eye-movement in the vertical plane and in comparing them with those for the horizontal plane. However, in order to facilitate interpretation and comparison, the several features of the records have been marked off and labeled.

In the case of Plate V the Roman numerals I, II, etc., number the successive lines of the records for movement in the horizontal plane; Roman numerals I′, II′, etc., number the corresponding lines on the records for movements in the vertical plane. The capital letters *A*, *B*, etc., mark off the successive portions of the records for movement in the horizontal plane which represent

the return sweep, the last pause of the preceding line, and the first of the succeeding line; capital letters A', B', etc., designate the corresponding portions of the records for movement in the vertical plane. Arabic numerals 1, 2, etc., number the pauses for the successive lines of the records for movement in the horizontal plane; Arabic numerals 1′, 2′, etc., number the corresponding pauses for the successive lines of the records for movement in the vertical plane.

In the case of Plate VI, Roman numerals I, II, etc., number the lines on the records for head- and eye-movement in the vertical plane; Roman numerals I′, II′, etc., mark off the corresponding areas on the records for head-movement alone. Capital letters A, B, etc., indicate the portions of the records containing the record of the return sweep in the case of the records for head- and eye-movement combined; capital letters A', B', etc., point out the approximately corresponding portions on the records for head-movement alone. The small letters a, b, etc., indicate in the case of both records typical deviations which are clearly indicative of head-movement; the small letters a', b', etc., point out on the records for head- and eye-movement combined typical deviations which are clearly indicative of eye-movement alone.

Since Plate V is chiefly intended to facilitate a comparison of the records for movement in the vertical plane with the corresponding records for movement in the horizontal plane, it may be desirable to read the records from bottom to top. For all other purposes the records for movement in the vertical plane should be read horizontally from left to right. Assuming the records to be read thus, upward or downward movements of the head or the eye are indicated by upward or downward deviations. If there were no head- or eye-movement during the pauses, the records of the pauses would be straight; if there were no such movement during the interval in which the eye passes from one fixation point to another, the series of dots and spaces representing the several pauses of a given line would likewise follow a straight line. That movement does take place in the vertical plane is very evident from the appearance of the records. To what extent this is

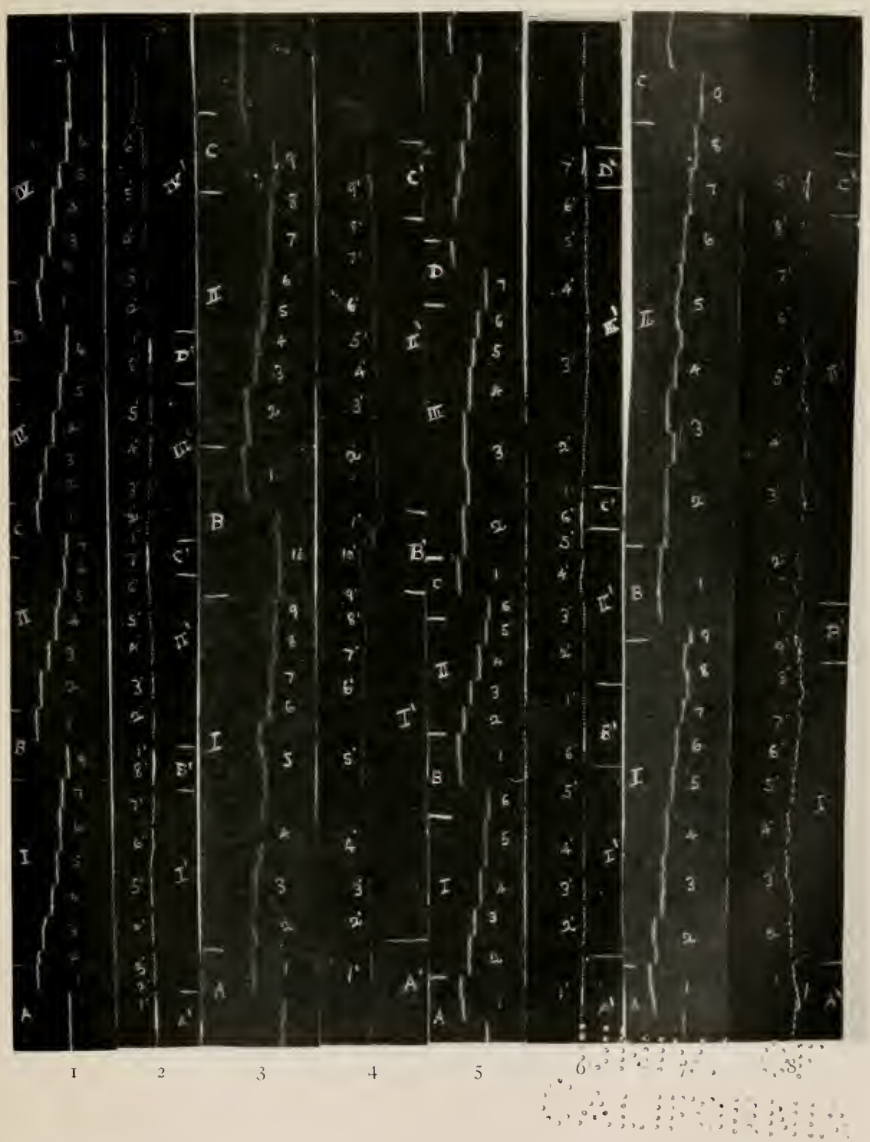
head-movement rather than eye-movement remains to be pointed out in connection with the analyses which follow.

2. *Comparison of records for the two planes.*—As previously indicated, Plate V makes possible a comparison of the records for movement in the vertical plane with the corresponding records for movement in the horizontal plane. Records 1 and 2 represent the silent and records 3 and 4 the oral reading of adult individual No. 12; records 5 and 6 represent the silent and records 7 and 8 the oral reading of adult individual No. 24. A general survey of the records, especially those for silent reading, shows that the grosser movements tend to affect both planes, i.e., deviations implying head- or eye-movement in the records of pauses in one plane are frequently accompanied by deviations in the corresponding records of the other plane. Note, for instance, in the case of records 1 and 2, line I, pauses 1–3; line II, pause 3; line III, pauses 1, 4, and 6; and line IV, pauses 1–5. Note, similarly, in the case of records 5 and 6, line I, pauses 1–4; line II, pause 4; and line III, pauses 2–5. The same tendency is in evidence in connection with oral reading, provided that the movement in the vertical plane is not too pronounced. In the case of records 3 and 4 some correspondence may be observed, but in the case of records 7 and 8 the vertical deviations are too pronounced as compared with the horizontal. These grosser movements, as will be pointed out later, are largely of the head variety.

A comparison of the records shows, further, that head- or eye-movement in the vertical plane, as indicated by deviations on the records for this plane, is also, in part at least, recorded on the records for movement in the horizontal plane, an upward movement being indicated by a crowding of the dots and a downward movement by a spreading of the dots. Note, for instance, Plate V, records 1 and 2, line I, pause 6, and records 7 and 8, line I, pauses 3, 7, 8, and 9, and line II, pauses 1, 3, 5, 6, and 9.

As previously indicated, the portion of the records for movement in the vertical plane which represents the last pause of the previous line, the first of the succeeding line, and the return sweep is frequently blurred on the records because of the close proximity of the records of the three components. This is particularly true

PLATE V



in the case of the records for silent reading, which represent a minimal amount of head-movement. It is therefore at times quite difficult to compare this part of the records for movement in the vertical plane with the corresponding part of the records for movement in the horizontal plane. An interesting exception is noticeable in the case of record 6, return sweep *D'*, at the end of line III. There was a decided upward movement here during the return sweep, and in consequence a marked downward movement during the subsequent fixation. Note the spreading of the dots in the upper portion of *D*, the corresponding horizontal record of the same pause. Oral records 3 and 4 afford even better instances for comparison. In the case of record 4, return sweep *B'*, the three components are very much in evidence. There was a downward movement during the last pause of line I and a marked downward movement during the latter part of the fixation pause which followed upon the return sweep. A careful examination of the corresponding portions of the records for movement in the horizontal plane shows very clearly the expected spreading of the dots. Note, further, return sweep *C'* of the same record and return sweeps *B'* and *C'* of record 8.

A particularly interesting comparison of movement in the two planes is made possible in connection with records 1 and 2 just after line IV. At the close of pause 6 of this line the reader made an upward sweep with the eyes of approximately two inches, this being followed after a brief fixation period by a downward return sweep. The fact that there were during these upward and downward sweeps also slight movements toward the right heightens the effect on the record for movement in the horizontal plane, the upward sweep being represented by a line running downward and slightly to the right and the downward sweep by a line running upward and slightly to the right.

3. *Head- and eye-movement in the vertical plane.*—As stated above, the records for head-movement and those for head- and eye-movement combined parallel each other in the case of Plate VI. The first and the last are, however, exceptions. The former is a record of light reflected from a polished bead fastened to the apparatus, being intended to detect possible vibrations of the

apparatus in the vertical plane. The latter is a record of head- and eye-movement combined; it illustrates in a striking manner the effects of binocular adjustment in so far as these appear on the records for the vertical plane. An examination of record 1 shows that vibrations of the apparatus are practically non-existent. A comparison of the remaining records indicates, however, that head-movement is to be reckoned with in this plane even more than in the horizontal plane, particularly in the case of oral reading. Records 2 and 3 represent the silent and records 4 and 5 the oral reading of adult individual No. 6—the second representing rather a maximal amount of head-movement and the third rather a minimal amount of eye-movement in connection with silent reading, the fourth being, on the other hand, fairly typical of a maximal amount of head-movement and the fifth of a minimal amount of eye-movement in the case of oral reading. Records 6 and 7 represent the silent and records 8 and 9 the oral reading of adult individual No. 6A—the sixth being typical of a minimal amount of head-movement and the seventh of a maximal amount of eye-movement in connection with silent reading, while the eighth represents distinctly a minimal amount of head-movement and the ninth an average amount of eye-movement in the case of oral reading.

Several types of head-movement are in evidence as in the case of the horizontal plane. The first and most obvious of these appears on the records in the form of rather marked irregular deviations. These are particularly in evidence in connection with oral reading. Note record 4 of Plate VI, also record 8 of Plate V. This form of head-movement appears to involve a rather continuous irregular oscillation of the head in the vertical plane, this being in all probability due largely to disturbances set up by articulation. It differs from head-movement of the first type for the horizontal plane in that it is much more irregular and in that it has a greater amplitude; it differs from the fourth type of the horizontal plane in being more continuous and more marked. Its form and size may be accounted for, in part at least, by the fact that the head moves less easily and less smoothly in the vertical than in the horizontal plane. The significant fact is that this type of head-

movement appears in common with the foregoing types on the records both for head-movement and for head- and eye-movement combined, the chief exceptions occurring at the points where the eyes move rapidly, as in the case of the connective movements. Compare records 4 and 5 for this purpose at points designated by *a*, *b*, *c*, etc.

A second type of head-movement appears on the records in the form of a rather gradual change in direction, implying a slow change in the position of the head. The degree of such shifting varies materially, being in some instances, especially in the case of silent reading, very slight, as in the case of record 2 of Plate VI; in other instances, particularly in connection with oral reading, it is quite marked, as in the case of record 8 of Plate VI. A comparison of records 2 and 3 and of records 8 and 9 of Plate VI shows that such movements are generally recorded on the records for both head-movement and head- and eye-movement combined. There are, however, some exceptions, particularly in the case of silent reading. The correspondence in the case of records 2 and 3, for instance, is not absolute; in part this is of course due to the frequency of the connective movements. This type of movement resembles somewhat the head-movement of the third type for the horizontal plane.

A third type of head-movement appears on the records in the form of a slight unsteadiness, implying a very slight disturbance of the head, and possibly at times of the film. It resembles head-movement of the fourth type for the horizontal plane in a general way, but differs from it in that enlargement does not show as definite wave-form, and in that the disturbance is less marked. At times such movement appears alone, as in the case of record 6 of Plate VI; at other times it may occur in connection with other types, as in the case of records 2 and 4 of Plate VI. It appears on the records both for head-movement and for head- and eye-movement combined.

An examination of the records for the purpose of determining the nature of eye-movement in the vertical plane reveals a variety of irregularities. Some of these are clearly indicative of divergent and convergent adjustment. It will be remembered that

divergence involves in the case of the horizontal plane an outward movement of both eyes and convergence an inward movement. Careful investigation has shown that these two types of adjustment also involve movement in the vertical plane, the eyes moving upward as well as outward in the case of divergence and downward as well as inward in the case of convergence (4). Since divergence is characteristic of the connective movements and convergence of fixation, the records for the return sweep and for the interfixation movements ought to show an upward trend and those for the fixation pauses ought to show a downward trend. An examination of a large number of records can leave no doubt as to the presence of these phenomena. Although it is ordinarily rather difficult to isolate the record for the return sweep, it is quite evident that it terminates frequently above the normal level of the records for the fixation pauses, and this in spite of the fact that the eyes actually pass downward in sweeping from the end of one line to the beginning of the next. Observe as very striking examples return sweep *D* of record 6 of Plate V, return sweep *B* of record 5 of Plate VI, and return sweeps *A*, *C*, and *F* of record 10 of Plate VI. To a certain extent this same tendency is in evidence in connection with practically all return sweeps. Unfortunately these portions of the records are often blurred in printing so that they do not stand out as clearly on the plates as they do on the films. The records for the interfixation movements, on the other hand, stand out so definitely that their character may be closely observed. Note, accordingly, the persistent upward tendency of these minute portions of the records. Observe particularly in the case of records 3, 5, 7, 9, and 10 of Plate VI the instances at points designated by 1′, 2′, 3′, etc. The convergent adjustment in connection with subsequent fixation pauses is also clearly in evidence, especially in connection with fixation pauses which follow upon the return sweeps. Note the downward trend of the records of such pauses at points designated by 1, 2, 3, etc. In the case of the fixation pauses which follow upon interfixation movements the effect of convergent adjustment is not as evident, largely because the adjustment is in such cases extremely minute. It is, however, in all probability, rarely, if ever, entirely absent. We shall speak

of this convergent adjustment in the vertical plane, as indicated by a downward trend of the records of fixation pauses, as "eye-movement of the first type."

A second type of eye-movement resembles eye-movement of the third type for the horizontal plane. It appears on the records in the form of rather isolated deviations, being accompanied in some cases by a slighter and more general disturbance. Record 7 of Plate VI is particularly typical in this respect; note the deviations at points designated by 1″, 2″, 3″, etc.; observe also the more general irregularities at other points along the record. This type of eye-movement appears particularly in connection with silent reading; in the case of oral reading it is in all probability largely obscured by the effects of head-movement. As in the case of the horizontal plane, this type of irregularity is in all probability largely due to lack of balance on the part of the muscles of the eyes.

It is not probable that the two types of eye-movement which have been described are all-inclusive. As in the case of the horizontal plane, there are certain indications of compensatory eye-movement; these are, however, so slight that it has not seemed wise to attempt their definite characterization with the present technique and extent of investigation.

Certain characteristics of the records of Plate VI remain to be pointed out. Records 2 and 3 represent the silent reading of adult individual No. 6. Observe in the case of record 3 the downward sweep from *a′* to *b′*. The reader fixated at this stage a point approximately two inches below the first line. An examination of the corresponding section of record 2, the record for head-movement, shows that these downward and upward movements of the eyes were executed without any appreciable amount of head-movement. Note incidentally the marked convergent adjustment which follows upon these movements, as indicated by the downward trend of the records for the subsequent fixation pauses, particularly the one which follows the upward sweep from *c′* to *d′*. Similar adjustments are strongly in evidence during subsequent initial fixation pauses, particularly in the case of those designated by 2, 3, 4, and 5. Note also the prevalence of head-movement of the third type in the case of record 2, particularly from *a* to *b*.

Records 4 and 5 represent the oral reading of the same individual, the former showing a rather marked amount of head-movement, most of which appears also on record 5. These records show very clearly, as do numerous others, that the eyes are carried with the head in the case of practically all head-movement occurring in connection with reading. This, however, does not prevent the eye from engaging in certain elaborate simultaneous adjustments, such as convergence; nor does it exclude the presence of slight compensatory adjustments on the part of the eyes; the connective movements appear to take place quite independently of head-movement, in part, no doubt, because of their extremely short duration. Note the correspondence in the records for head-movement and for head- and eye-movement combined at points designated by *a*, *b*, *c*, etc. Note also the exceptions at points where the records for the connective movements appear.

Records 6 and 7 represent the silent reading of adult individual No. 6A. An examination of these records shows that head-movement may in the case of some individuals be almost completely absent, while eye-movement may be quite marked. Record 6 gives practically no evidence of head-movement; record 7, on the other hand, gives indications of very marked eye-movement. Records 8 and 9 represent the oral reading of the same individual. The records are unique in that they represent a minimal amount of head-movement in connection with oral reading. Note, however, the correspondence between head- and eye-movement, particularly at points indicated by *a*, *b*, *c*, etc. The marked deviation at the beginning of record 9 represents, as in the case of record 3, purposive movement, the reader fixating a point approximately two inches below the first line. In general, the adjustment resembles that discussed in connection with record 3. There is in evidence, however, a rather unusual amount of independent eye-movement. Compare the records particularly at points between *b'* and *c'*, *d'* and *e'*, and *e'* and *b*. The downward movement at *e'* is not easily accounted for. It is possible that the reader was about to repeat the original downward sweep, but that he corrected himself before reaching the fixation point. It is possible, too, that he may have become aware indirectly of a considerable portion

of the first part of the line, and so may not have been in need of accurate fixation while these words were being pronounced. Another interesting feature appears near the end of this record. Instead of the usual return sweep of the eye, there was at this stage a movement of the head downward and toward the left. Just why the movement should have been so pronounced, or why it should have occurred at all, is difficult to tell. To all appearances it did not interfere with the reading, for the subject continued uninterruptedly and with but little subsequent adjustment. It should be noticed incidentally that there was in connection with this shift of the head a certain amount of independent eye-movement; note particularly the deviation at 3″. It is quite evident from this and other instances that there may be rather marked eye- and head-movement without serious visual disturbance. It is not probable, however, that the image is carried far beyond the fovea centralis in connection with such eye- and head-movement.

C. SUMMARY AND CONCLUSIONS REGARDING THE MOTOR BEHAVIOR OF THE EYE

An adequate characterization of eye-movement is, as we have seen, quite impossible unless the effects of head-movement can be eliminated. Even the most carefully devised headrest does not appear to exclude the latter entirely. Accordingly, it has been our task to analyze the complexes and to distinguish between head- and eye-movement. Several types of head-movement have been discovered for each plane. In the case of the horizontal plane four distinct types have been observed. The first involves a series of rather uniform oscillations of the head, or possibly vibrations of the apparatus; the second represents a tendency on the part of the head to move rapidly in a direction opposite to that in which the eyes move during interfixation movements, the movement occurring at about the same time as the interfixation movements, and particularly in connection with oral reading; the third type involves a more gradual change in the position of the head, occurring also especially in connection with oral reading; the fourth type implies a general unsteadiness of the head, this

being also particularly characteristic of oral reading In the case of the vertical plane three somewhat similar types have been pointed out. The first involves a rather continuous irregular oscillation of the head; the second implies a gradual change in the position of the head; the third represents a very slight unsteadiness of the head; each of these three types is most marked in connection with oral reading.

The several different types of head-movement for the two planes, with the possible and at least partial exception of the second type for the horizontal plane, appear on the records for head- and eye-movement combined, showing that the eyes are for the most part held in position and carried along with the head during head-movement occurring in connection with reading. This, however, does not exclude the possibility of a slight simultaneous compensatory movement of the eyes, nor does it of course prevent independent eye-movement at times when the head is practically at rest.

Several different types of eye-movement have also been distinguished for each plane. In the case of the horizontal plane we have, of course, first of all the connecting movements, namely, interfixation movements, including refixations, and the return sweep, the duration of the former ranging from 0.01 to 0.03 second and that of the latter from 0.03 to 0.05 second. The most striking characteristic of these movements appears in the fact that the two eyes do not cover equal distances in executing them, the leading eye (in space) passing invariably over a greater extent than the eye which follows. Such movement implies divergent adjustment.

In connection with the fixation pauses three distinct types of eye-movement were pointed out for the horizontal plane. The first involves a gradual convergent movement of the eyes, this being most strongly in evidence in the case of the initial fixation pause of each line; the second type represents a rapid movement of both eyes at the beginning of certain fixation pauses in a direction opposite to that of the preceding connective movement; the third type involves isolated irregular excursions of the eyes in either direction, rarely more than one occurring in connection with any one fixation, such movement being due in all probability

to lack of muscular balance. There are also indications of compensatory eye-movement, but it has not been possible to characterize this definitely.

Somewhat similar types of eye-movement are in evidence in connection with the vertical plane. There is, to begin with, a gradual upward movement of the eyes in connection with the interfixation movements and the return sweep, this being indicative of divergent adjustment. Two types have been pointed out as especially characteristic of fixation pauses. The first represents a downward movement of the eyes during fixation, this being indicative of convergent adjustment; the second type resembles eye-movement of the third type for the horizontal plane, being indicative of isolated irregular excursions of the eyes and also possibly of a slighter and somewhat more general disturbance, the irregularities in either case being due to lack of muscular balance. As in the case of the horizontal plane, there are slight indications of compensatory eye-movement, the definite characterization of which has not been attempted.

Assuming that the last types of eye-movement, the third in the case of the horizontal plane and the second in the case of the vertical plane, are due largely to lack of muscular balance, we have endeavored to account for the remaining types on the basis of a common principle of explanation. Such movements are obviously closely related to divergent and convergent binocular adjustment. In fact, they represent for the most part various phases of such adjustment. The connecting movements of the eyes are clearly accompanied by divergence, the degree of such adjustment varying rather directly with the speed and extent of the movement in question. Divergence, it will be remembered, involves an upward and an outward movement of the eyes. This being the case, we have at once an explanation of the difference in the distances covered by the two eyes in connection with the connecting movements as well as for the upward trend of such movements. If no such adjustment occurred in connection with such movements, the two eyes would cover equal distances. Divergence introduces a disturbing factor by virtue of the fact that it involves a change in the relative position of the two eyes. In view of the fact that

both eyes move outward (and upward) in connection with such adjustment, the leading eye (in space) passes during connective movements beyond the point it would have reached had there been no divergent adjustment; the eye which follows, on the other hand, fails to reach the point it would have reached had there been no divergence because it moves in a direction opposite to that of the connecting movements in question. As a result the leading eye actually passes over a greater extent than the eye which follows in connection with such movements. But divergence involves an upward as well as an outward movement of the eyes. This fact accounts, of course, for the upward trend which is in evidence in connection with the connection movements in the case of the horizontal plane. This upward trend is, as a matter of fact, also in evidence on the records for the horizontal plane; not as definitely, however, since it is somewhat complicated with other factors, such as the movement of the films.

In connection with fixation, convergent adjustment is strongly in evidence. Convergence as opposed to divergence involves an inward movement of the eyes. This fact accounts for eye-movement of the first type in the case of both the horizontal and the vertical plane. Reading at close range, as in the case of the printed page, necessitates, of course, near accommodation. Since the connecting movements involve divergence, convergent adjustment must necessarily be effected during fixation or clear vision would not be possible. The convergent adjustment in question involves accordingly, on the one hand, an inward movement of the eyes which has been designated as eye-movement of the first type for the horizontal plane, and, on the other hand, a downward movement of the eyes which has been characterized as eye-movement of the first type for the vertical plane. Eye-movement of the second type for the horizontal plane represents a more elementary form of eye-movement than binocular adjustment, namely, a tendency for both eyes to move sympathetically in the same lateral direction. As Dr. Judd points out in his most thoroughgoing study of convergence and divergence (5), such movements represent an early and crude stage of ocular behavior—a stage in which "recognition of position in depth is undeveloped." The infant represents such

a stage for a time. In consequence he experiences presently a vague consciousness of confusion in the presence of objects situated at varying depths. This increasing confusion tends to excite new forms of motor adjustment until convergence is accidentally hit upon. However, even then the tendencies toward the more elementary forms of movement do not necessarily disappear; they are rather controlled by the superior motives of perception which demand the higher forms of binocular motor co-ordination. This is brought out in an interesting manner by the fact that stimulations of the occipital visual area result only in sympathetic lateral movements of the eyes, while an excitation of the higher association centers of the cerebrum leads to convergent movements of the eyes. Every visual percept is thus in its inception essentially a confused mass of experience, clearness appearing only in proportion as the more elementary forms of sympathetic ocular behavior are overcome by the higher forms of binocular adjustment.

The reading pause represents essentially such a process, the recognition of words and meanings appearing gradually as the motor adjustment progresses. It must be remembered, of course, that the perceptual process is rarely limited to specific pauses, prefixational vision making significant contributions; so much so, in fact, that the reading pause may in many cases represent a comparatively late stage in the total process. But even then it represents clearly a progressive form of motor adjustment paralleled by increasing clearness in recognition. Early and partial recognition simply tends to facilitate the process.

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4. *Ibid.*
5. *Ibid.*, p. 412.

CHAPTER VI

GENERAL SUMMARY AND CONCLUSION[1]

This investigation was undertaken primarily for the purpose of making a careful analysis of the reading process, both silent and oral, as represented by a large group of individuals varying widely in age and accomplishment. The problem was approached chiefly by way of a critical study of eye-movements, the latter involving in the case of reading a succession of fixation pauses and connective movements. Since the perceptual process is essentially limited to the fixation pause, the latter has been the chief object of this investigation, being studied intensively from the standpoint of the average number per line (90 mm.), the average duration, the location within the line, and the accompanying motor behavior of the eyes. The connective movements have also been critically studied in view of their intimate relationship with the fixation pause.

The average number of pauses was found to vary from 4.1 to 10.8 per line for silent reading and from 6.1 to 11.5 for oral reading. In terms of the average number of words perceived per pause the figures vary in the case of silent reading from 2.15 to 0.93 and in the case of the oral from 1.62 to 0.86. These figures are in close agreement with the results of other studies.

The average duration of pauses varies from 214 to 470 σ for silent reading and from 230 to 520 σ for oral reading. These durations (silent reading) are somewhat higher than those found by previous investigators, partly because a larger and more varied group has been examined in this case and partly, if not largely, because the reading was in this connection of the careful rather than the rapid type.

A study of the location of fixation pauses has shown that there is a slight tendency toward fixating the apperceptive unit centrally with reference to the width of the unit of course, no method having

[1] Consult also the summaries at the end of chapters iv and v.

yet been devised which makes possible the precise location of the path of the fixation point with reference to the height of the printed word or line. This tendency toward central location is facilitated, on the one hand, by the fact that we are in the habit of regarding most objects in the visual field as units and by contributions received through peripheral vision and context; it is interfered with, on the other hand, by such factors as defective motor control, tendencies toward short-lived motor habits, and objective peculiarities demanding analysis. And, finally, there can be no doubt that the demands of perception are frequently met quite as well by end fixations as by central fixation. While the words within which the pauses fall do not appear to belong to one class rather than to another, it is quite evident that short words which combine readily with others to form apperceptive units escape fixation most frequently.

The total perception time per line is the product of the average number and the average duration of pauses. It represents the reading time with the exception of the brief interval consumed by the connective movements. It constitutes, therefore, a rather reliable index to the rate of reading. In the case of the present study the average perception time per line varies from 1,140 to 3,684.8 σ for silent reading and from 1,702 to 4,454 σ for oral. In terms of the number of words read per second the figures range from 8.68 to 2.71 for silent reading and from 5.88 to 2.24 for oral. The most rapid silent reader read a little more than three times as fast as the slowest and the most rapid oral reader a little more than twice as fast as the slowest. A temporary change in the rate of reading appears to affect the duration rather than the number of pauses, the former being decreased as the rate is increased. It is probable, however, that a permanent change in the rate of reading, especially one effected by judicious practice, would also involve changes in the number of pauses. The fact that there is a higher degree of correlation between the average perception time per line and the average number of pauses than between the average perception time per line and the average duration of pauses points in this direction. There is ample evidence that a large percentage of readers, particularly those who are not

good visualizers, is compelled to resort to "scanning" in order to attain final efficiency in the speed of silent reading. This fact, although almost entirely ignored thus far, is bound to be of material significance in determining the reorganization of practices and methods of teaching reading, particularly if it can be shown that scanning is not opposed to good quality in comprehension.

A comparison of the several groups representing different stages of individual development has brought out few significant differences. The number of pauses is uniform, and the duration of the pauses nearly so. The only possible difference occurs in the case of the children who represent slightly longer duration times than the adults, in all probability because the motor adjustments involved in fixation have not been as fully perfected as in the case of the adults. No marked difference is in evidence in connection with the location of the pauses. The average fixation or reading time is also quite uniform. This fact is borne out by the results of other studies involving careful reading. The most marked differences between children and adults appear in connection with irregularities. Refixations and average deviations particularly are much more marked in the case of children than in the case of adults, showing no doubt that the motor habits of children have not been as thoroughly established as those of adults.

All in all, the results of the tests with children point toward the existence of a critical transition stage—a stage which appears to mark the passage from a slow and cumbersome to a rapid adult type of reading. The age at which an individual emerges from this stage varies materially, coming, in some instances at least, as early as the second grade, and in others materially later. In the case of the present study the second-grade pupils had passed this stage for the silent but not for the oral reading; the third grade had passed it in neither case as yet. After this stage is once passed and the mechanics of reading is mastered, the reading rate tends to remain rather constant. This is particularly true in cases where speed is somewhat subordinated to comprehension and where the reading materials are carefully graded. Such facts point, of course, to the conclusion that efficiency in the speed of reading

may be attained at a comparatively early age. The significance of this cannot be overestimated in an age when educative information comes so largely through channels involving extensive reading.

Individual variation is strongly in evidence in connection with the results of the present investigation. In fact, it is the most outstanding characteristic, not only in the case of the total results in connection with speed and comprehension, but also in the case of most of the minor factors. This is in close keeping with the results of most other investigations. The prevalence and the marked character of such variation are bound to figure prominently in determining new standards and practices in the teaching of reading.

The differences between silent and oral reading, although perhaps not as marked as might be expected, are clearly in evidence. The subjects of the present investigation read 57 per cent more material silently than orally. There is in evidence, further, in connection with silent reading, a very definite tendency toward positive correlation between rate and comprehension, rapid readers representing a higher quality of comprehension than the slow. No such correlation is in evidence in the case of the oral reading. In fact, there are some indications that an increase in rate may be inconsistent with good quality of comprehension. The differences between the two types of reading would undoubtedly have been more marked had the subjects been trained to distinguish between the two. As a matter of fact, reading has until recently been taught so poorly that it is extremely hazardous to speak of standards for either type of reading, as well as of standard differences between the two types. Training in silent reading has been almost unthought of, and whatever may have been accomplished in the case of oral reading during the earlier grades has not infrequently been undone because of indifferent practices in connection with the later grades.

Before attempting a critical characterization of the motor behavior of the eyes in connection with reading it was necessary to determine the nature and the prevalence of head-movement in so far as this is represented on the reading records. It was

found to be rather prevalent in both planes, being, of course, most marked in the case of oral reading. With few exceptions the eyes are carried along with the head during such movement. As a result head-movement is very easily mistaken for eye-movement. Head-movement for both planes falls readily into a few classes. The first represents a simple oscillation of the head, this being more marked and more irregular in the case of the vertical than in the case of the horizontal plane; the second represents a tendency of the head to move (horizontal plane) in a direction opposite to that in which the eyes move during interfixation movements; the third represents a slow shifting of the head (both planes) during fixation; the fourth involves a general unsteadiness of the head (both planes).

The most important types of eye-movement (both planes) are closely related to the binocular adjustment which accompanies the connective movements and fixation, the connective movements being accompanied by divergence and fixation by convergence. Divergence involves an upward and outward movement of the eyes and convergence a downward and inward movement. The former accounts for the unequal distances traversed by the two eyes in the case of the connective movements as well as for the upward trend of such movements; the latter accounts for the inward and upward movement of the eyes during fixation, the inward movements being in evidence on the records for movement in the horizontal plane and the upward movements on the records for movement in the vertical plane. Another type of eye-movement (horizontal plane) is essentially opposed to divergent and convergent adjustment. It represents a tendency toward a more elementary type of adjustment—an adjustment involving a sympathetic movement of both eyes in the same lateral direction at the beginning of a fixation. As has been pointed out, only the superior perceptual motives are able to overcome such tendencies and to lead to successful convergent adjustment. A final type of eye-movement involves certain irregularities in connection with fixation, these being in all probability largely due to lack of muscular balance and to possible functional disturbances.

Finally, the facts in the case point unmistakably toward some degree of recognition during the earliest stages of the ordinary fixation pause. The nature of convergent adjustment itself implies a progressive and consciously directed process of recognition. There is, in other words, a consciousness of confusion, or of lack of clearness, which continues to incite motor adjustment until the cleared-up percept appears, this being in turn accompanied and followed by elaborate associational processes—processes involving assimilation and organization.

INDEX

Monograph No. 4 (In Press)

Experimental Studies in Arithmetic. By GEORGE S. COUNTS, PH.D., Professor of Education, University of Delaware.

This monograph, which will be about 125 pages in length, is based on material collected from Cleveland, Grand Rapids, and a number of individual schools through the use of the Cleveland Survey Arithmetic Tests. Mr. Counts has worked out in some detail the types of errors which children make in these arithmetic tests, has calculated the correlations between the different types of tests, and has shown the relation between age and success in arithmetic. The work will be of immediate use to supervisors and administrative officers and will suggest to teachers methods of handling students who have difficulty with their arithmetic combinations.

Monograph No. 5 (In Press)

Types of Reading Ability as Exhibited through Tests and Laboratory Experiments. By CLARENCE TRUMAN GRAY, PH.D., Instructor in Education, University of Texas.

Mr. Gray carried on a series of studies of reading for one year with the aid of a subsidy supplied by the General Education Board. He photographed the eyes of a number of children who had been selected through carefully conducted tests in the Elementary School and in the High School of the University of Chicago. By means of the tests he was able to distinguish different types of ability to read; by means of the laboratory experiments he arrived at an explanation of a number of these types. The work undertaken by Mr. Gray was carried further by a number of teachers who worked on these special cases and improved the ability of the pupils through special training. Reports on these special cases are included in the monograph.

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